Total Maximum Daily Load Development for the Back Bay, North Landing River, and Pocaty River Watersheds

E.coli, and *Enterococci* Due to Recreation Use Impairments, pH Due to Aquatic Life Use Impairment, and Total Phosphorus Due to Low Dissolved Oxygen in Aquatic Life Use Impairments

DRAFT

Prepared for:
Virginia Department of Environmental Quality

Submitted by:
MapTech, Inc.
Draft Submitted:
October 23, 2013

New River-Highlands
RC&D

MapTech, Inc.
3154 State Street
Blacksburg, VA 24060
(540) 961-7864

New River Highlands RC&D
325 East Main Street, Suite E-2
Wytheville, VA 24382

Page intentionally blank

ACKNOWLEDGEMENTS

Virginia Department of Environmental Quality (VADEQ), Central Office

VADEQ, Tidewater Regional Office

Virginia Department of Conservation and Recreation (VADCR)

City of Chesapeake

City of Virginia Beach

Virginia Department of Health

Virginia Dare Soil and Water Conservation District

HRSD

Back Bay Restoration Foundation

USFWS – Back Bay Wildlife Refuge

Virginia Department of Game and Inland Fisheries

Area Citizens

Page intentionally blank

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Background and Applicable Standards

There are seven different impaired streams in this study area, North Landing River, Pocaty River, Beggars Bridge Creek, Ashville Bridge Creek, Muddy Creek, Hell Point Creek – Upper, and Hell Point Creek – Lower.

All seven segments have bacterial impairments; two for violating the freshwater primary contact recreational standard (*E. coli*) and five for violating the transition and saltwater primary contact recreational standard (*enterococci*). Two of the segments were listed for violating the dissolved oxygen standard and one segment for violating the pH standard. **Table ES. 1** shows the details of the impairments.

In Virginia, once a water body violates a given standard, a Total Maximum Daily Load (TMDL) must be developed. The TMDL is a pollution budget that determines the amount of pollutant the water body can receive in a given period of time and still meet the intended standard.

A natural condition assessment for low dissolved oxygen concluded that excessive nutrients, in particular phosphorus, were responsible for the low dissolved oxygen impairments in Pocaty River and Ashville Bridge Creek. Therefore, phosphorus TMDL was developed for these two segments. A pH TMDL was developed for the pH impairment on Ashville Bridge Creek. The seven bacteria impairments were organized into five groups. The two freshwater impairments (North Landing River and Pocaty River) were two separate groups, each with its own TMDL. A separate *enterococci* TMDL was developed for Beggars Bridge Creek (transitional and saltwater). A second *enterococci* TMDL was developed for the drainage area containing both Ashville Bridge Creek and Muddy Creek (transitional and saltwater). A third *enterococci* TMDL was developed for the drainage area containing upper Hell Point Creek and lower Hell Point Creek (transitional and saltwater).

Table ES. 1 Impairments in the study area.

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2010 River Miles/ Square Miles[1]**	**2010 Listing Violation%**	**Impairment Location Description**
North Landing River (Middle) VAT-K41R_NLR03A06	*E. coli*	2006	1.43	22.2 EC	From the area East of Fentress Landing Field , between confluence with West Neck Creek and Pocaty River.
Pocaty River VAT-K41R_PCT01A02	*E. coli* Dissolved Oxygen	2012 2002	7.24	14.7 EC 44.4 DO	From the headwaters at river mile 3.92 to confluence with North Landing River at mile 0.00.
Beggars Bridge Creek VAT-K42E_BBC01A04	*Enterococcus*	2006	0.033[1]	31.4 Ent	From the confluence of numerous unnamed tributaries (RM 1.34) near Dawley Corners and extends downstream to the mouth at the confluence with Shipps Bay.
Hell Point Creek (Lower) VAT-K42E_HPC02A04	*Enterococcus*	2004	0.026[1]	38 Ent	From the area at intersection of creek and canal upstream of monitoring station and ends at mouth, confluence with North Bay.
Hell Point Creek (Upper) VAT-K42E_HPC01A00	*Enterococcus*	2006	0.030[1]	27.8 Ent	From the headwaters (west of Sandbridge) downstream to RM 0.73, intersection of creek with canal near mouth.
Muddy Creek VAT-K42E_MDY01A04	*Enterococcus*	2004	0.040[1]	41.7 Ent	From the confluence with Ashville Bridge Creek to its mouth, at the confluence with North Bay.
Ashville Bridge Creek (Lower) VAT-K42E_ASH01A06	*Enterococcus* Dissolved Oxygen pH	2006 2006 2012	0.022[1]	25 Ent 13.8 DO 11.1 pH	From the lower portion of Ashville Bridge Creek, between Hell Point and Muddy Creeks.

EC - Based on the interim instantaneous *E. coli* standard of 235 cfu/100ml.
Ent - Based on the interim instantaneous *enterococci* standard of 104 cfu/100ml

TMDL Endpoint and Water Quality Assessment

Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard for freshwater and *enterococci* for estuarine water. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 mL and *enterococci* target was a geometric mean not exceeding 35 cfu/100 mL. A translator developed by VADEQ was used to convert fecal coliform values to *E. coli* and *enterococci* values.

The phosphorus TMDLs developed as a result of the low DO impairments were developed utilizing the reference watershed approach. In the reference watershed approach, the load from the unimpaired watershed is used as a target load for the impaired watershed. The low pH TMDL endpoint for Ashville Bridge Creek was a pH of 6 std. units.

Source Assessment

Sources of bacteria and sediment were identified and quantified in the study area. Sources included point sources as well as non-point sources. The quantification of sources is important to determine the baseline of current conditions that is causing the impairment. Sources of bacteria included human, livestock, wildlife, pets, as well as permitted point sources. Phosphorus sources coming from various activities such as farming and development, as well as, permitted point sources were quantified.

Modeling Procedures

Computer modeling is used to relate the sources on the ground to the water quality in the streams and rivers. This is important since not every colony of bacteria or every amount of sediment in the watershed ends up in the streams and rivers. The computer models help quantify the portion of bacteria and phosphorus within the study area that ends up in the stream and reach watershed outlet.

The computer modeling process consists of several steps. First, the characteristics of the drainage area including land use, slopes, stream network, soil properties, are entered into the model. The parameters influencing bacteria and phosphorus are also entered into the corresponding model. A process known as calibration is then conducted by comparing model simulations with monitored field data. Model parameters are adjusted during calibration to minimize the error between simulated and monitored values. This process is conducted for hydrology (flow) as well as water quality. Once the model is calibrated, it is then used to determine the existing water quality conditions in the study area and may be used to determine the reductions necessary to meet the water quality standard or endpoint. No computer models were used for the pH but rather spreadsheet calculations to estimate needed load reductions.

Hydrology (for Bacteria Modeling)

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform. For the tidally influenced subwatersheds, the Steady State Tidal Prism Model, which is used by VADEQ for modeling tidally impacted waterbodies, was implemented within the HSPF framework to model the tidally influenced segments in conjunction with lateral free-flowing creeks. For purposes of modeling the study area, inputs to streamflow and in-stream fecal bacteria, the drainage area was divided into eleven (11) subwatersheds.

Daily precipitation data was available near the study area at the Wallaceton Lk Drummond NCDC COOP station # 448837, Suffolk Lake Kilby NCDC COOP station #448192, and Norfolk South NCDC COOP station # 446147.

The model was calibrated for hydrologic accuracy using paired watershed approach utilizing the calibrated parameters from the nearby Nansemond River watershed.

Fecal Coliform

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct sources of uncontrolled discharges, direct deposition by wildlife, direct deposition by livestock, and direct inputs from sewer overflows. Contributions from all of these sources were updated to current conditions to establish existing conditions for the watershed.

The fecal coliform calibration and validation were conducted using monitored data collected at multiple VADEQ monitoring stations for the period of October 2003 to September 2009.

Phosphorus

The model used in this study was the *Visual Basic™* version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The target TMDL load for the impaired watersheds is the average annual load in metric tons per year (t/yr) from the area-adjusted reference watershed under existing conditions. The selected reference watershed was Feeder Ditch to Dismal Swamp from Lake Drummond since it’s low DO impairment is due to natural conditions. To reach the TMDL target goal (2,400 kg/yr for Pocaty River and 516 kg/yr for Ashville Bridge Creek), different scenarios were run with GWLF.

pH

pH calculations were conducted utilizing a spreadsheet. Calculations were based on average flow within Ashville Bridge Creek.

Accounting for Natural Background Pollutant Contributions (Bacteria)

TMDLs consist of waste load allocations (WLAs) and load allocations (LAs). Load allocation (LA) is the portion of a receiving waters loading capacity attributed either to existing or future nonpoint sources of pollution, or to natural background sources. LA estimates depend on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).

For bacteria, the pollutant of concern in this TMDL, water quality monitoring represents existing conditions of the sum of anthropogenic and natural background pollutants. Water quality modeling mimics the sum condition. Nevertheless, because wildlife represents the major source of natural background bacteria pollution, it was quantified and a separate load assigned. In the final TMDL equation, the natural background contributions are included in the LA component.

Load Allocation Scenarios

The next step in the TMDL processes was to reduce the various source loads to levels that would result in attainment of the water quality standards or endpoints. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. The final TMDL information is shown in **Table ES. 2**.

Table ES. 2 Annual in-stream cumulative pollutant loads modeled after allocation in the study area impairments.

Pollutant	Units	Impairment	WLA[1]	LA	MOS	TMDL
E. coli	cfu/yr	**North Landing River**	6.25E+12	1.73E+14	*Implicit*	1.79E+14
E. coli	cfu/yr	**Pocaty River**	2.58E+12	1.21E+14	*Implicit*	1.24E+14
Enterococci	cfu/yr	**Beggars Bridge Creek**	6.79E+11	2.55E+13	*Implicit*	2.62E+13
Enterococci	cfu/yr	**Ashville Bridge Creek + Muddy Creek**	7.95E+11	2.15E+13	*Implicit*	2.23E+13
Enterococci	cfu/yr	**Hell Point Creek (upper) + Hell Point Creek (lower)**	2.04E+12	2.66E+13	*Implicit*	2.87E+13
Phosphorus	kg/yr	**Pocaty River**	129.39	2,030.59	240.00	2,399.98
Phosphorus	kg/yr	**Ashville Bridge Creek**	34.46	429.42	51.55	515.43
pH	g/yr of H^+	**Ashville Bridge Creek**	0.0	2,075	230	2,305

[1] WLA by permit can be found in the corresponding allocation chapters.

Implementation

The goal of the TMDL program is to establish a path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. This report represents the first phase of that effort for the impairments in the study area. The next step will be more monitoring to better establish the sources of TSS. Development of TMDL implementation plans (IP) will follow the phased TMDL process. The final step is to implement the TMDL IPs and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate water quality management plan. With successful completion of implementation plans, Virginia continues the process of restoring impaired waters and enhancing the value of this important resource.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned, a new designated use, or a subcategory of a use, the current designated use must be removed. The state must also demonstrate that attaining the designated use is not feasible. Information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens as well as EPA will be able to provide comment during this process.

Public Participation

During development of the TMDL for the impairments in the study area, public involvement was encouraged through a first public meeting (2/27/2013), and a final public meeting October 22, 2013. An introduction of the agencies involved, an overview of the TMDL process, details of the pollutant sources, and the specific approach to developing the Back Bay, North landing River, and Pocaty River watershed TMDLs were presented at the first of the public meeting. Public understanding of and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting. Written comments were addressed in the final document.

Page intentionally blank

1. INTRODUCTION

1.1 Regulations Background

The Clean Water Act (CWA) that became law in 1972 requires that all U.S. streams, rivers, and lakes meet certain water quality standards. The CWA also requires that states conduct monitoring to identify waters that are polluted or do not otherwise meet standards. Through this required program, the state of Virginia has found that many stream segments do not meet state water quality standards for protection of the six beneficial uses: recreation/swimming, aquatic life, wildlife, fish consumption, shellfish consumption, and public water supply (drinking).

When streams fail to meet standards, the stream is “listed” in the current Section 303(d) report as requiring a Total Maximum Daily Load (TMDL). Section 303(d) of the CWA and the U.S. Environmental Protection Agency’s (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) both require that states develop a Total Maximum Daily Load (TMDL) for each pollutant. A TMDL is a "pollution budget" for a water body; that is, it sets limits on the amount of pollution that a water body can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS).

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia’s 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the *“Board shall develop and implement a plan to achieve fully supporting status for impaired waters”*. The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process. Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

1.2 *Watershed Characteristics*

The Back Bay North Landing River and Pocaty River watersheds (USGS Hydrologic Unit Code 03010205) are located in the Cities of Chesapeake and Virginia Beach, Virginia. These watersheds are a part of the Dismal Swamp and Albemarle Sound subbasin, which drains to the Atlantic Ocean from North Carolina. The location of the watersheds is shown in **Figure 1.1**. The drainage area of the areas of interest within this project is approximately 77,000 acres.

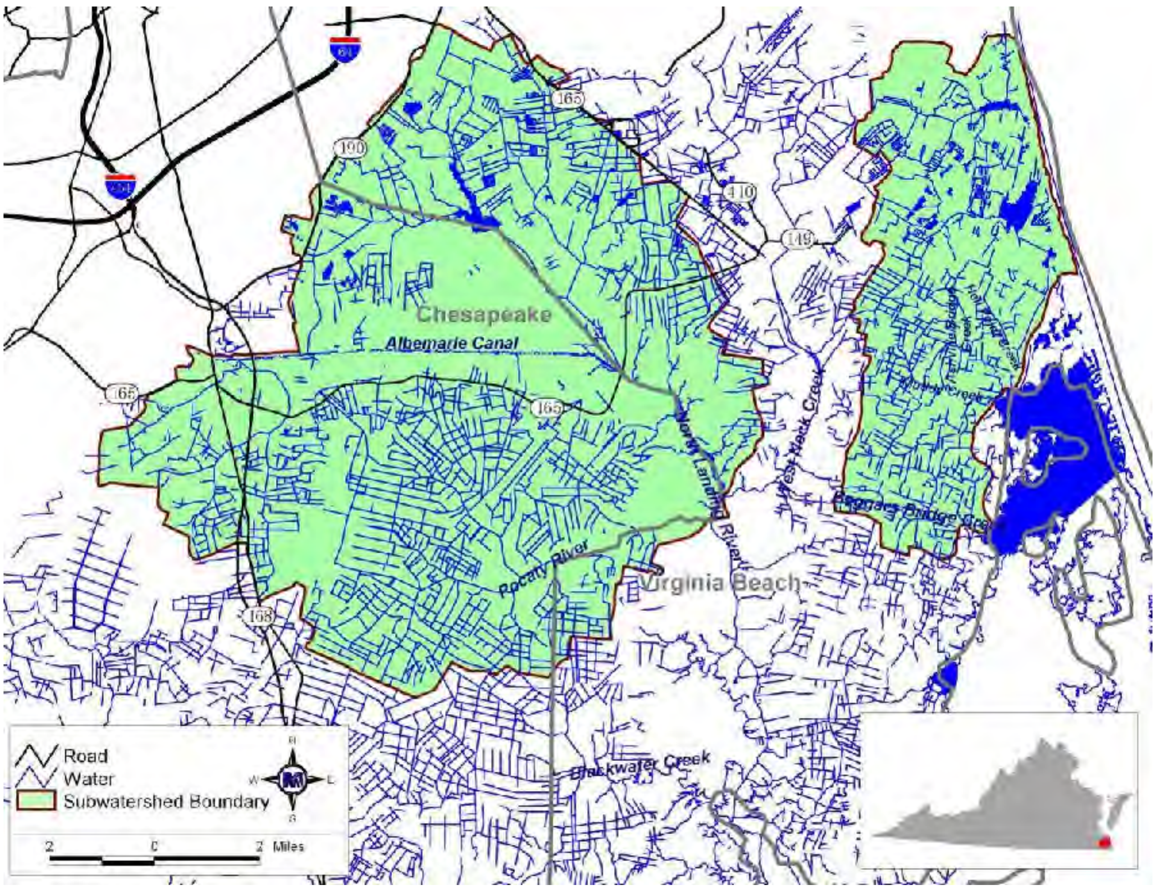

Figure 1.1 Location of the Back Bay and North Landing River area of interest.

The Back Bay, North Landing River and Pocaty River watersheds are located within the level III Middle Atlantic Coastal Plain (63) (Level IV subsets – Albemarle Silty Lowlands and Tidal Marshes (63b) and Barrier Islands and Coastal Marshes (63d). The

Middle Atlantic Coastal Plain ecoregion is a low, nearly flat plain, with many swampy or marshy areas. It consists primarily of loblolly-shortleaf pine with patches of oak, gum, and cypress near major streams. Poorly drained soils are common especially in lowest areas. Elevations range from 0 to 100 feet above sea level.

(http://www.eoearth.org/article/Ecoregions_of_Delaware%2C_Maryland%2C_Pennsylvania%2C_Virginia%2C_and_West_Virginia_%28EPA%29).

As for the climatic conditions in the Back Bay, North Landing River and Pocaty River watershed, during the period from 1953 to 2007 Back Bay Wildlife Refuge, Virginia (NCDC station# 440385) received an average annual precipitation of 45.15 inches, with 56% of the precipitation occurring during the May through October growing season (SERCC, 2011). Average annual snowfall is 2.9 inches, with the highest snowfall occurring during January (SERCC, 2011). The highest average daily temperature of 85.9 ºF occurs in July, while the lowest average daily temperature of 31.7 ºF occurs in January (SERCC, 2011).

Land use in the study area was characterized using the National Land Cover Database 2006 (NLCD). Wetlands make up the largest land use in the watersheds, accounting for over 30% of the land area. Residential and crop lands are sizable as well, accounting for approximately 18% each. Approximately 13% of the land in the study area is open space. Forest, water, and pasture lands account for approximately 6% each. Barren and commercial land uses are insignificant in size and comprise less than 1% of the study area. Detailed land use by impairment is given in **Appendix B**.

1.3 Recreation Use and Aquatic Life Use Impairments

There are seven different impaired segments in this study area, some of which are impaired for multiple parameters. The impairments include Beggars Bridge Creek, Hell Point Creek (Lower), Hell Point Creek (Upper), Muddy Creek, North Landing River, Ashville Bridge Creek, and Pocaty River (**Figure 1.2, Figure 1.3** and **Table 1.1**). The sections below detail the conditions in each impaired stream segment.

The Virginia Department of Environmental Quality has recently moved towards a more cost effective approach to conducting TMDLs. In the new approach, TMDLs may be developed for large areas containing several impaired stream segments. These geographic units are herein called “nested TMDL units” or “NTUs” because they consist of watersheds that formerly were the basis of TMDL projects. Using this approach, NTUs are designed to provide TMDLs that are cost effective, while being scientifically defensible.

The building blocks for the NTUs are U. S. Geological Survey (USGS) 12-digit hydrologic units (HUCs). The HUCs were attributed with land cover and use values through GIS-extraction of information from the National Land Classification Dataset (2001), hydrologic connectivity from the USGS National Watershed Boundary dataset, and U. S. Environmental Protection Agency Ecoregion Level III features. HUCs were aggregated in an upstream fashion if their properties indicated the likelihood of similar TMDL conclusions. Aggregation continued until a HUC was encountered that had a substantially different potential TMDL conclusion, was a headwater, or had exceeded the cluster size limit. When a TMDL is to be developed for an impaired segment within a nested area, a decision is made as to whether develop the TMDL only for that segment or expand the TMDL development for the entire NTU.

For the remainder of this document, the analysis will be conducted for five areas. The two impairments violating the *E. coli* standard (North Landing River and Pocaty River) will be treated as two separate areas. The five impairments violating the *enterococci* standard will be grouped into three areas. Beggars Bridge Creek will be treated as a separate area. Hell Point Creek (upper) and Hell Point Creek (lower) will be considered as the second area. Finally, the third area will consist of Ashville Bridge Creek and Muddy Creek.

1.3.1 North Landing River - Middle (VAT-K41R_NLR03A06)

North Landing River in the City of Virginia Beach, VA, flows southeast before the Virginia/North Carolina State line.

The North Landing River from the area east of Fentress Landing Field, between confluence with West Neck Creek and Pocaty River (1.43 stream miles) was listed as impaired on the 2006 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 5BNLR010.75 had a 22.2% bacteria standard violation rate in the 2010 assessment.

1.3.2 Pocaty River (VAT-K41R_PCT01A02)

Pocaty River in the City of Virginia Beach, VA, flows northeast before its confluence with the North Landing River.

The Pocaty River from the headwaters at river mile 3.92 to confluence with North Landing River at mile 0.00 (7.24 stream miles) was listed as impaired on the 2002 303(d) list for not supporting the aquatic life use. VADEQ monitoring station 5BPCT001.79 had a 44.4% minimum dissolved oxygen standard violation rate in the 2010 assessment. The Pocaty River was added to the 2012 impaired waters list for not supporting the recreation/swimming use. VADEQ monitoring station 5BPCT001.79 had a 14.7% violation rate.

1.3.3 Beggars Bridge Creek (VAT-K42E_BBC01A04)

Beggars Bridge Creek, in the City of Virginia Beach, VA, flows east before its confluence with Shipps Bay. Beggars Bridge Creek at the confluence of numerous unnamed tributaries (RM 1.34) near Dawley Corners and extends downstream to the mouth at the confluence with Shipps Bay. An area of 0.033 square miles was listed as impaired on the 2006 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 5BBBC000.76 had a 31.4% violation rate in the 2010 assessment.

1.3.4 Hell Point Creek (Lower) (VAT-K42E_HPC02A04)

Hell Point Creek, in the City of Virginia Beach, VA, flows south before its confluence with North Bay.

Hell Point Creek, from the area at intersection of creek and canal upstream of monitoring station and ending at its mouth and confluence with North Bay (0.026 square miles), was listed as impaired on the 2004 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 5BHPC000.00 had a 38% violation rate in the 2010 assessment.

1.3.5 Hell Point Creek (Upper) (VAT-K42E_HPC01A00)

Hell Point Creek, in the City of Virginia Beach, VA, flows south before its confluence with North Bay. Hell Point Creek from the headwaters (west of Sandbridge) downstream to RM 0.73, intersection of creek with canal near mouth (0.030 square miles) was listed as impaired on the 2006 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 5BHPC001.46 had a 27.8% bacteria standard violation rate in the 2010 assessment.

1.3.6 Ashville Bridge Creek - Lower (VAT-K42E_ASH01A06)

Ashville Bridge Creek in the City of Virginia Beach, VA, flows south before its confluence with Muddy Creek. Ashville Bridge Creek from the lower portion of Ashville Bridge Creek, between Hell Point and Muddy Creeks (0.022 square miles) was listed as impaired on the 2006 303(d) list for not supporting the aquatic life and recreation/swimming uses. VADEQ monitoring station 5BASH002.20 had a 25% bacteria standard violation rate and a 13.8% minimum dissolved oxygen standard violation rate in the 2010 assessment. The segment was also listed in the 2010 integrated report for having a 11.1% violation of the pH standard.

1.3.7 Muddy Creek (VAT-K42E_MDY01A04)

Muddy Creek in the City of Virginia Beach, VA, flows south-southeast before its confluence with North Bay. Muddy Creek from the confluence with Ashville Bridge Creek to its mouth, at the confluence with North Bay (0.04 square miles) was listed as impaired on the 2006 303(d) list for not supporting the recreation/swimming use. VADEQ monitoring station 5BMDY000.00 had a 41.7% bacteria standard violation rate in the 2010 assessment

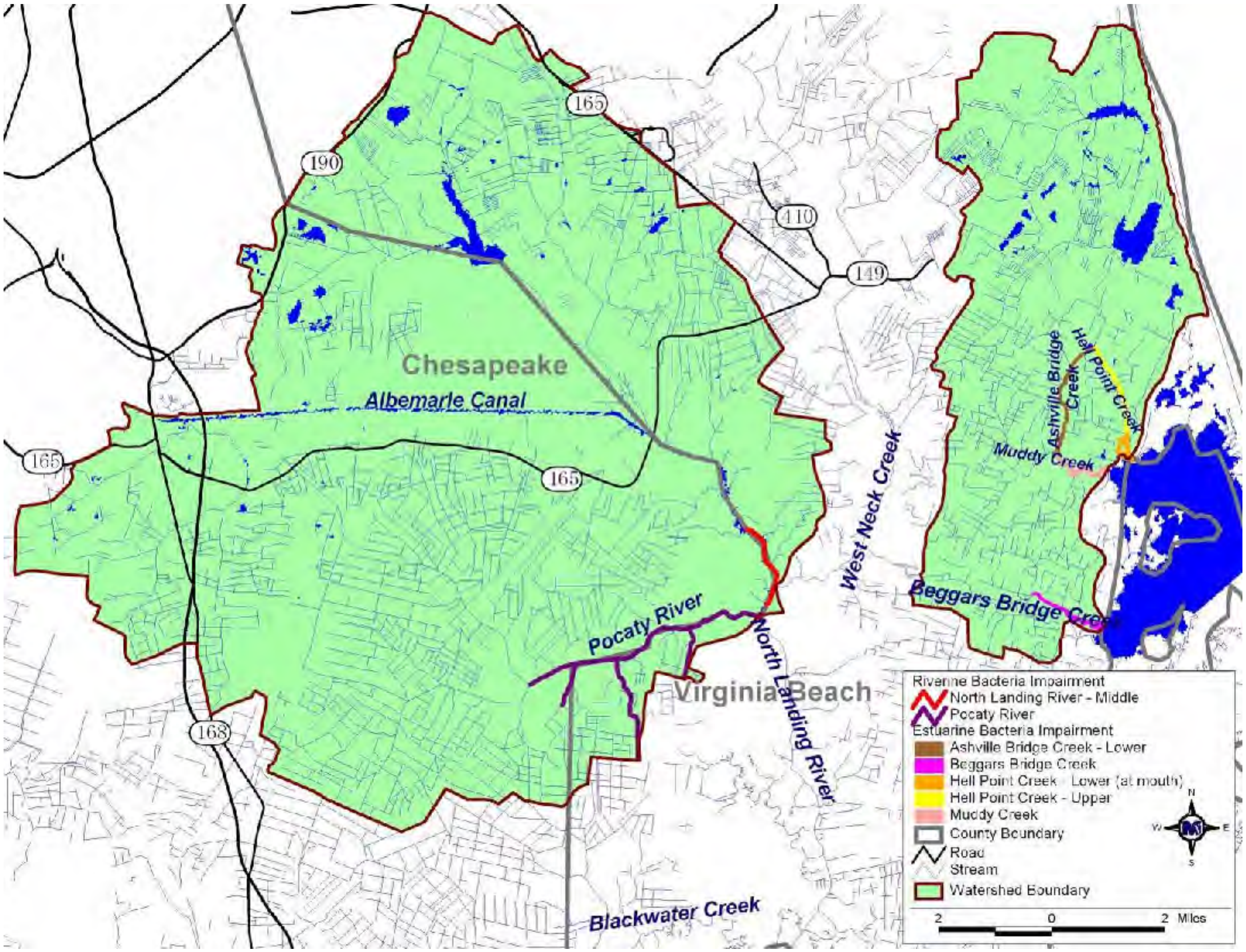

Figure 1.2 ***E.coli* and *enterococci* impaired segments in the study area.**

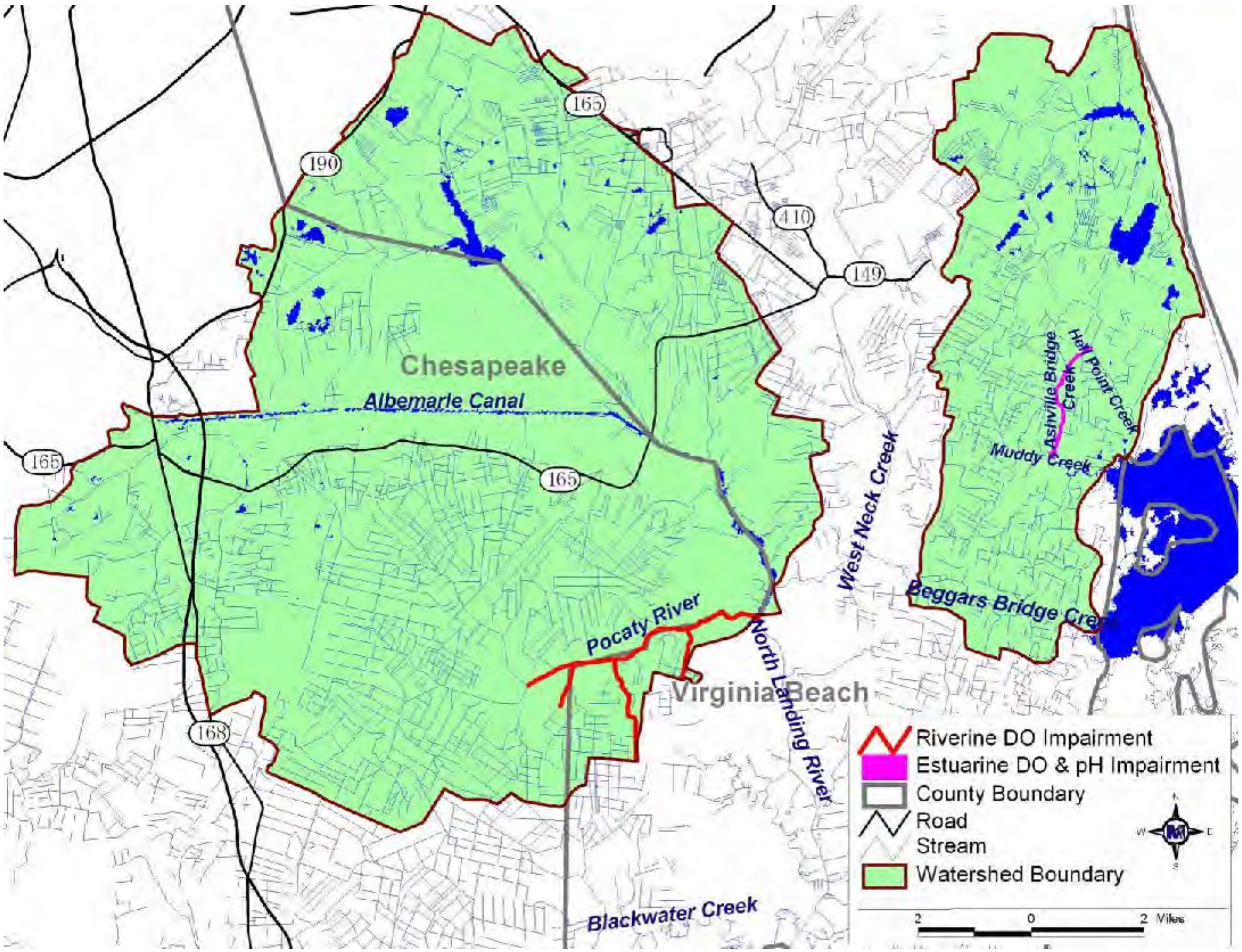

Figure 1.3 DO and pH impaired segments in the study area.

Table 1.1 Impairments within the study area.

Stream Name Impairment ID	**Impairment(s) Contracted**	**Initial Listing Year**	**2010 River Miles/ Square Miles[1]**	**2010 Listing Violation%**	**Impairment Location Description**
North Landing River (Middle) VAT-K41R_NLR03A06	*E. coli*	2006	1.43	22.2 EC	From the area East of Fentress Landing Field , between confluence with West Neck Creek and Pocaty River.
Pocaty River VAT-K41R_PCT01A02	*E. coli* Dissolved Oxygen	2012 2002	7.24	14.7 EC 44.4 DO	From the headwaters at river mile 3.92 to confluence with North Landing River at mile 0.00.
Beggars Bridge Creek VAT-K42E_BBC01A04	*Enterococcus*	2006	0.033[1]	31.4 Ent	From the confluence of numerous unnamed tributaries (RM 1.34) near Dawley Corners and extends downstream to the mouth at the confluence with Shipps Bay.
Hell Point Creek (Lower) VAT-K42E_HPC02A04	*Enterococcus*	2004	0.026[1]	38 Ent	From the area at intersection of creek and canal upstream of monitoring station and ends at mouth, confluence with North Bay.
Hell Point Creek (Upper) VAT-K42E_HPC01A00	*Enterococcus*	2006	0.030[1]	27.8 Ent	From the headwaters (west of Sandbridge) downstream to RM 0.73, intersection of creek with canal near mouth.
Muddy Creek VAT-K42E_MDY01A04	*Enterococcus*	2004	0.040[1]	41.7 Ent	From the confluence with Ashville Bridge Creek to its mouth, at the confluence with North Bay.
Ashville Bridge Creek (Lower) VAT-K42E_ASH01A06	*Enterococcus* Dissolved Oxygen pH	2006 2006 2010	0.022[1]	25 Ent. 13.8 DO 11.1 pH	From the lower portion of Ashville Bridge Creek, between Hell Point and Muddy Creeks.

EC - Based on the interim instantaneous *E. coli* standard of 235 cfu/100ml.
Ent - Based on the interim instantaneous *enterococci* standard of 104 cfu/100ml

Page intentionally blank

2. BACTERIAL TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

According to Virginia Water Quality Standard 9 VAC 25-260-5, the term 'water quality standards' means " provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act."

Virginia Water Quality Standard 9 VAC 25-260-10 (Designation of uses) states:

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

⧫

E. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§ 301(b)(1)(A) and (B) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.

⧫

H. The [State Water Quality Control] Board may remove a designated use which is not an existing use, or establish subcategories of a use, if the board can demonstrate that attaining the designated use is not feasible because:

1. *Naturally occurring pollutant concentrations prevent the attainment of the use;*

2. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;*

3. *Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;*

4. *Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use;*

5. *Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or*

6. *Controls more stringent than those required by §§ 301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.*

I. The board may not remove designated uses if:

1. *They are existing uses, unless a use requiring more stringent criteria is added; or*

2. *Such uses will be attained by implementing effluent limits required under §§ 301(b)(1)(A) and (B) and 306 of the Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control.*

Virginia's current bacterial standard uses *E. coli* and *enterococci* as bacterial indicators. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals; there is a strong correlation between these and the incidence of gastrointestinal illness. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. Prior to January 2003, Virginia's water quality standard in fresh water for swimming/recreational use was based on fecal coliform rather than *E.coli*. The change was based on EPA's recommendation that all states adopt an *E. coli* or *enterococci* standard for fresh water and *enterococci* criteria for marine waters by 2003. The EPA pursued the states' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and *enterococci*) and the incidence of gastrointestinal illness than with fecal coliform.

Virginia's current criteria are outlined in Section 9 VAC 25-260-170 and read as follows:

A. The following bacteria criteria (colony forming units (CFU)/100 ml) shall apply to protect primary contact recreational uses in surface waters, except waters identified in subsection B of this section:

E.coli bacteria shall not exceed a monthly geometric mean of 126 CFU/100 ml in freshwater.

Enterococci bacteria shall not exceed a monthly geometric mean of 35 CFU/100 ml in transition and saltwater.

1. *See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.*
2. *Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.*
3. *If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E.coli CFU/100 ml .*
4. *If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 CFU/100 ml.*
5. *For beach advisories or closures, a single sample maximum of 235 E.coli CFU/100 ml in freshwater and a single sample maximum of 104 enterococci CFU/100 ml in saltwater and transition zones shall apply.*

2.2 Selection of a Bacteria TMDL Endpoint

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the bacteria impairments in the Back Bay and Pocaty and North Landing River watersheds, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations. In order to remove a waterbody from a state's list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard.

Since modeling provided simulated output of *enterococci* and *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using the geometric mean standard. Therefore, the in-stream *enterococci* and *E. coli* targets for the TMDLs in this study were a monthly geometric mean not exceeding 35 cfu/100 mL and 126 cfu/100mL, respectively.

2.3 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal bacteria monitoring data in the Back Bay, North Landing River and Pocaty River watersheds. An examination of data from water quality stations used in the 303(d) assessment was performed. Sources of data and pertinent results are discussed.

2.3.1 Inventory of Water Quality Monitoring Data

The primary sources of available fecal bacteria information are:

- Bacteria enumerations from 13 VADEQ in-stream monitoring stations with data from January 2000 to February 2013

2.3.1.1 VADEQ Water Quality Monitoring for TMDL Assessment

Data from in-stream water samples, collected at VADEQ monitoring stations from January 2000 to February 2013 (**Figure 2.1**) were analyzed for fecal coliform (**Table 2.1**). Samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting fecal coliform concentrations to 235 cfu/100 mL or less for *E. coli* and 104 cfu/100 mL or less for *enterococci*. As a matter of economy, samples showing concentrations below 25 cfu/100 mL or in excess of a specified cap (*e.g.*, 2,000 or 8,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 25 cfu/100 mL most likely represent concentrations below 25 cfu/100 mL, and reported concentrations of 2,000 or 8,000 cfu/100 mL most likely represent concentrations in excess of these values.

E. coli and enterococci samples were also collected to evaluate compliance with the state's current bacterial standard. **Table 2.2** and **Table 2.3** summarize the *E. coli* and *enterococci* samples collected at the in-stream monitoring stations, respectively. Information in the tables is arranged in alphabetical order by stream name, then from downstream to upstream station location. **Appendix A** contains graphs of the violation record from the available data.

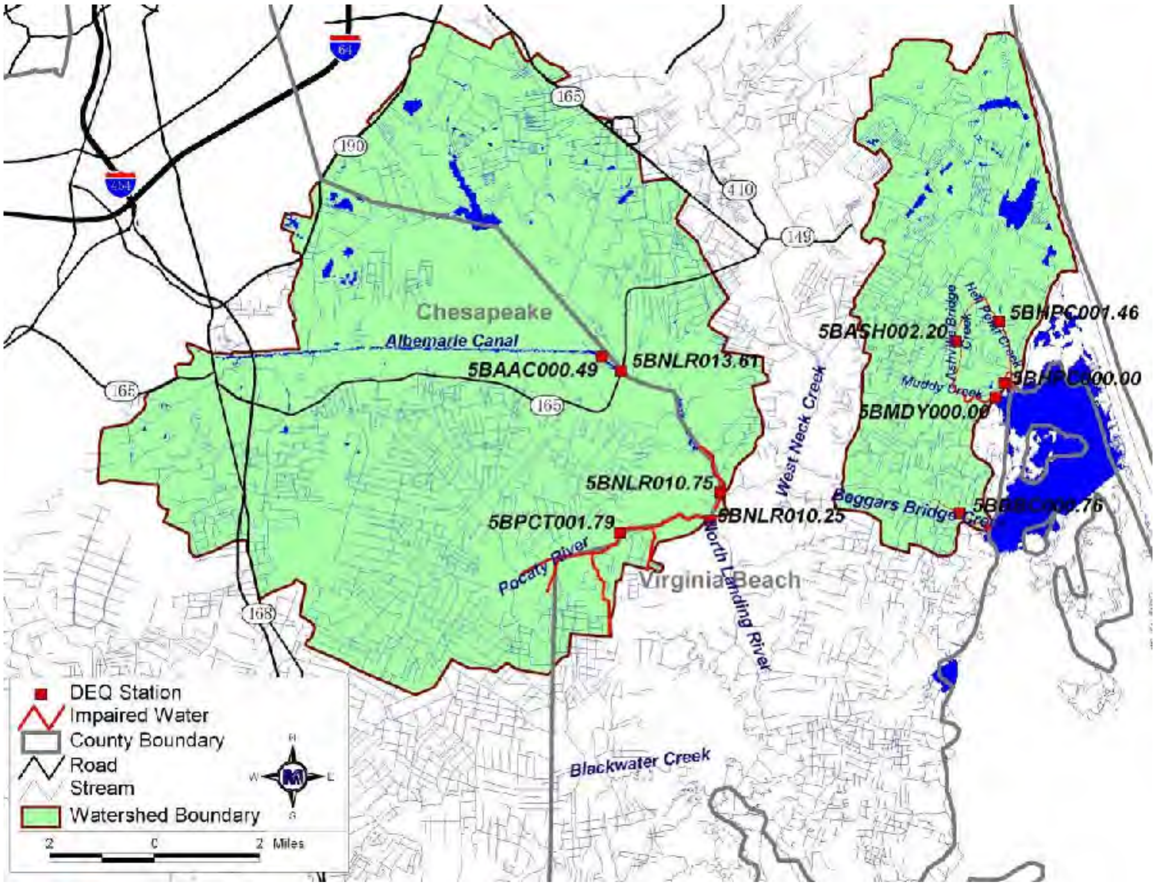

Figure 2.1 **Location of VADEQ water quality monitoring stations in the Back Bay, North Landing River and Pocaty River watersheds.**

Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 2000 – January 2013.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Ashville Bridge Creek	5BASH002.20	05/03 - 09/06	20	25	2000	246	63	471	35%
Beggars Bridge Creek	5BBBC000.76	02/00 - 01/13	85	25	2000	216	100	429	32%
Hell Point Creek	5BHPC000.00	05/00 - 01/13	65	25	2900	152	50	430	18%
Hell Point Creek	5BHPC001.46	02/00 - 01/13	84	25	2000	184	75	415	18%
Muddy Creek	5BMDY000.00	02/00 - 01/13	86	25	2200	240	100	456	31%
North Landing River	5BNLR003.83	01/00 - 12/06	25	25	150	75	100	40	4%
North Landing River	5BNLR005.56	01/00 - 12/06	25	25	200	87	100	47	12%
North Landing River	5BNLR007.56	01/00 - 12/06	25	25	200	80	100	42	4%
North Landing River	5BNLR009.68	08/09	1	50	50	50	50	NA	0%
North Landing River	5BNLR010.25	01/00 - 12/06	25	25	500	106	100	96	16%
North Landing River	5BNLR010.75	01/00 - 12/06	25	25	580	130	100	148	16%
North Landing River	5BNLR013.61	01/00 - 01/13	89	25	2000	118	50	261	12%
Pocaty River	5BPCT001.79	01/00 - 01/13	82	25	2300	232	100	420	34%

NA – Not applicable
[1] Based on the instantaneous fecal coliform standard of 400 cfu/100mL.

Table 2.2 Summary of *E coli* (cfu/100mL) data collected by VADEQ from July 2002 – February 2013.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Ashville Bridge Creek	5BASH002.20	07/03 - 05/04	5	10	400	158	130	152	20%
Beggars Bridge Creek	5BBBC000.76	07/02 - 05/04	11	10	560	83	20	161	9%
Hell Point Creek	5BHPC000.00	07/02 - 07/03	4	40	800	330	240	327	50%
Hell Point Creek	5BHPC001.46	07/02 - 05/04	10	10	250	55	25	74	10%
Muddy Creek	5BMDY000.00	07/02 - 05/04	11	10	380	71	25	116	9%
North Landing River	5BNLR003.83	07/02 - 12/06	10	20	220	54	25	61	0%
North Landing River	5BNLR005.56	08/05 - 12/06	10	10	380	69	25	111	10%
North Landing River	5BNLR007.56	07/02 - 12/06	10	10	150	48	25	47	0%
North Landing River	5BNLR009.68	08/09	1	10	10	10	10	NA	0%
North Landing River	5BNLR010.25	07/02 - 12/06	10	10	320	76	25	103	10%
North Landing River	5BNLR010.75	07/02 - 12/06	10	10	700	154	25	258	20%
North Landing River	5BNLR013.61	07/02 - 02/13	65	10	2000	84	25	251	5%
Pocaty River	5BPCT001.79	07/02 - 01/13	58	10	1400	121	50	214	10%

NA – Not applicable

[1] Based on the instantaneous fecal coliform standard of 235 cfu/100mL.

Table 2.3 Summary of *enterococci* (cfu/100mL) data collected by VADEQ from February 2000 – January 2013.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Ashville Bridge Creek	5BASH002.20	07/03 - 09/06	20	10	2000	224	25	469	25%
Beggars Bridge Creek	5BBBC000.76	07/02 - 01/13	62	10	2000	321	50	629	31%
Hell Point Creek	5BHPC000.00	07/02 - 01/13	53	10	1200	133	25	232	25%
Hell Point Creek	5BHPC001.46	07/02 - 01/13	61	10	2000	217	50	474	25%
Muddy Creek	5BMDY000.00	07/02 - 01/13	63	10	2000	355	75	653	35%
North Landing River	5BNLR003.83	07/2002	1	10	10	10	10	NA	0%
North Landing River	5BNLR005.56	07/2002	1	10	10	10	10	NA	0%
North Landing River	5BNLR007.56	07/2002	1	10	10	10	10	NA	0%
North Landing River	5BNLR009.68	08/2009	1	10	10	10	10	NA	0%
North Landing River	5BNLR010.25	07/2002	1	10	10	10	10	NA	0%
North Landing River	5BNLR010.75	07/2002	1	10	10	10	10	NA	0%
North Landing River	5BNLR013.61	07/02 - 03/04	11	10	800	155	70	237	36%
Pocaty River	5BPCT001.79	07/02 - 03/04	9	10	800	217	70	298	33%

NA – Not applicable

[1] Based on the current instantaneous *enterococci* standard of 104 cfu/100mL.

3. BACTERIA SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal bacteria in the study area. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into point and nonpoint sections. The representation of the following sources in the model is discussed in the modeling appendix. To adequately represent the spatial variation in the watershed, the study area was divided into eleven (11) subwatersheds (**Figure 3.1**). Source assessment is conducted on subwatershed level where estimates of all potential pollutants are generated for each individual subwatershed.

3.1 Assessment of Permitted Sources

One individual point source is permitted to discharge to surface water bodies in the study area through the Virginia Pollutant Discharge Elimination System (VPDES) that is expected to contain fecal bacteria. This permit is listed in **Table 3.1**. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain an *E. coli* concentrations below 126 cfu/100mL, the current standard. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill pathogens. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. Typically, if minimum TRC levels are met, bacteria concentrations are reduced to levels well below the standard.

There are three single family home (domestic) permits within the study area (**Table 3.2**).

Two (2) MS4 (Municipal Stormwater) point sources are permitted in the Virginia Beach Coastal Area through the Virginia Pollutant Discharge Elimination System (VPDES). These point sources have MS4 permits, and are located in the Cities of Virginia Beach and Chesapeake (**Table 3.3**). MS4 systems are not permitted for fecal control and therefore do not use chlorination practices. US Navy-Auxiliary Landing Field, Fentress

(Permit #: VPA01003) is a non-discharge permit located in the North Landing River watershed. The wastewater from this facility is stored in aerated lagoons and then used for irrigation of crop land. Application is applied on a rotating basis between 5 different fields where only one field is used per month. According to the NMP, operational limits are in place ranging from application rates to time restraints. There is no discharge of any wastewater directly to North Landing River.

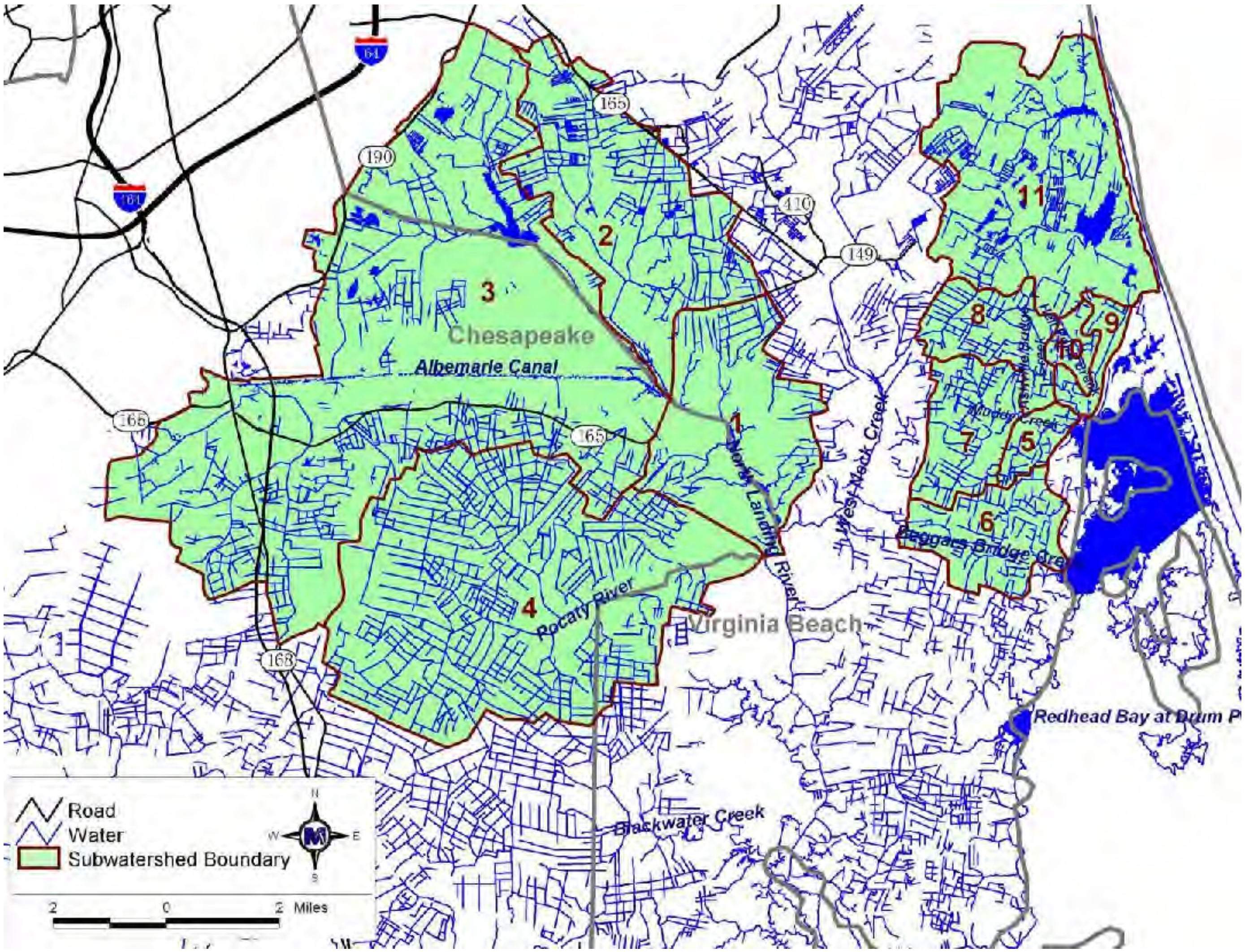

Figure 3.1 Subwatersheds within the study area.

Table 3.1 Summary of VPDES permitted point sources permitted for fecal bacteria control in the study area.

Permit	Receiving Stream(s)	Facility Name	Permitted for *E. coli* Control
VA0062391	Hell Point Creek	Indian Cove Resort Association Incorporated	Y

Table 3.2 Summary of VPDES domestic permitted point sources permitted for fecal bacteria control in the study area.

Permit	Receiving Stream(s)	Facility Name	Permitted for *E. coli* Control
VAG403053	Ditch to Intercoastal Waterway	True Way Evangelistic Church	Y
VAG403065	UTRIB to North Landing River	Battlefield Golf Club at Centerville	Y
VAG403048	North Landing River	Private Residence	Y

Table 3.3 Summary of MS4 permitted point sources in the study area.

Permit	Facility Name
VA0088676	Virginia Beach
VA0088625	Chesapeake

3.2 Assessment of Nonpoint Sources

In the study area, both residential and agricultural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage disposal systems, land application of waste (biosolids, livestock), livestock, wildlife, and pets. Sources were identified and enumerated. Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

Population, housing units, and type of sewage treatment from U.S. Census Bureau (USCB, 1990, 2000) were calculated using GIS (**Table 3.4).** In the U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank, or a cesspool or the sewage is disposed of in some other way. The Census category “Other Means” includes houses that dispose of sewage other than by public sanitary sewer or a private septic system. Ten percent of the houses included in this category were assumed to be disposing of sewage via straight pipes.

The number of houses with septic systems was estimated by subwatershed. The accuracy of the initial estimates was enhanced by obtaining geographic information from counties detailing the locations of septic systems. Resulting estimates were shared with regional Health Departments and feedback was obtained and used in adjusting numbers. Adjustments were made to initial estimates of total number of houses and number of houses with septic systems based on county data. The number of houses with failing septic systems was estimated based on the assumption that each septic systems fails, on average, once during an expected lifetime of 30 years. The estimates shown in **Table 3.4** are given by subwatershed which correspond to the geographic illustration in **Figure 3.1**.

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal bacteria is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal bacteria to surface waters.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity. A survey of septic pump-out contractors, previously performed by MapTech (MapTech, 1999), showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard.

MapTech previously sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 mL (MapTech, 1999). An average fecal coliform density for human waste of 13,000,000cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

Table 3.4 Human population, housing units, houses on sanitary sewer, septic systems, and straight pipes for areas contributing to impaired segments in the study area.

Sub-watershed	Impairment Group	Human Population	Housing Units	Homes with Sewer	Homes with Septic	Estimated Homes with Straight Pipes	Estimated Homes with Failing Septic Systems
1	North Landing River	5,521	1,935	1,729	197	1	15
2	North Landing River	28,607	9,656	9,558	75	2	24
3	North Landing River	80,044	28,408	27,106	1,258	4	82
4	Pocaty River	4,007	1,342	472	840	3	55
5	Muddy Creek/Ashville Bridge Creek	71	23	0	22	0	2
6	Beggars Bridge Creek	444	172	0	169	0	9
7	Muddy Creek/Ashville Bridge Creek	354	143	0	140	0	8
8	Muddy Creek/Ashville Bridge Creek	1,447	469	373	93	0	6
9	Hell Point Creek	82	49	35	13	0	1
10	Hell Point Creek	72	44	25	18	0	2
11	Hell Point Creek	22,907	8,355	8,286	58	1	12
Total		143,556	50,596	47,584	2,883	11	216

3.2.2 Biosolids

Between 1999 and 2011 biosolids were applied to fields within the study area (**Table 3.5**). The total amount of applied biosolids identified by location was 1,711 dry tons. This amount was applied mostly North Landing River and Pocaty River areas. The task of regulating biosolids applications is the responsibility of the Virginia Department of Environmental Quality. Biosolids are required to be spread according to sound agronomic requirements with consideration for topography and hydrology. All applications are done so in accordance with an approved Nutrient Management Plan. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids) however; actual applications may have densities far less than this amount. Application rates must be limited to a maximum of 15 dry tons/acre per three-year period.

Table 3.5 Application of biosolids within the study area (1999 – 2011).

Year	Sub-watershed	Impairment Group	Dry Tons
1999	1	North Landing River	532
2007	1	North Landing River	136
2007	4	Pocaty River	308
2008	1	North Landing River	268
2008	2	North Landing River	224
2008	4	Pocaty River	167
2011	1	North Landing River	49
2011	4	Pocaty River	27
Total			1,711

3.2.3 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the study area watershed and were the only pets considered in this analysis. Cat and dog populations were derived from American Veterinary Medical Association Center for Information Management demographics in 1997. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was previously measured by MapTech. Fecal coliform density for dogs and cats was previously measured from samples collected by MapTech. A summary of the data collected is given in **Table 3.6**. **Table 3.7** lists the domestic animal populations for impairments in the study area.

Table 3.6 Domestic animal population density, waste load, and fecal coliform (FC) density.

	Dog	Cat
Population Density (an/house)*	0.534	0.598
Waste load (g/an-day)**	450	19.4
FC Density (cfu/g)	480,000	9

* animals per house
** grams per animal per day

Table 3.7 Estimated domestic animal populations in areas contributing to impaired segments in the study area.

Sub-watershed	Impairment Group	Dogs	Cats
1	North Landing River	1,033	1,157
2	North Landing River	5,156	5,774
3	North Landing River	15,170	16,988
4	Pocaty River	717	803
5	Muddy Creek/Ashville Bridge Creek	12	14
6	Beggars Bridge Creek	92	103
7	Muddy Creek/Ashville Bridge Creek	76	86
8	Muddy Creek/Ashville Bridge Creek	250	280
9	Hell Point Creek	26	29
10	Hell Point Creek	23	26
11	Hell Point Creek	4,462	4,996
Total		27,017	30,256

3.2.4 Livestock

The predominant type of livestock in the study area is beef cattle, although other types of livestock identified were considered in modeling the watershed. **Table 3.8** gives a summary of livestock populations in the study area. Animal populations were based on communication with VADEQ, local Soil and Water Conservation District (SWCD), watershed visits, and verbal communication with citizens at the first public meeting.

Table 3.8 Livestock populations in areas contributing to impaired segments in the study area.

Sub-watershed	Impairment Group	Beef	Beef Calves	Beef Replacements	Horse
1	North Landing River	44	22	22	25
2	North Landing River	9	5	5	40
3	North Landing River	213	107	107	93
4	Pocaty River	833	416	416	387
5	Muddy Creek/Ashville Bridge Creek	0	0	0	2
6	Beggars Bridge Creek	5	2	2	222
7	Muddy Creek/Ashville Bridge Creek	5	2	2	21
8	Muddy Creek/Ashville Bridge Creek	4	2	2	17
9	Hell Point Creek	0	0	0	0
10	Hell Point Creek	0	0	0	0
11	Hell Point Creek	3	2	2	13
Total		1,116	558	558	820

Values of fecal coliform density of livestock sources were based on sampling previously performed by MapTech (MapTech, 1999a). Reported manure production rates for livestock were taken from American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in **Table 3.9**.

Table 3.9 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)	Waste Storage Die-off factor
Beef stocker (850 lb)	51.0	101,000	NA
Beef calf (350 lb)	21.0	101,000	NA
Beef replacement (600 lb)	33.1	101,000	NA
Horse (1,000 lb)	51.0	94,000	NA

Fecal bacteria produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.*, pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. **Table 3.10** shows the average percentage of collected livestock waste that is applied throughout the year. Second, grazing livestock deposit manure directly on the land where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities may have drainage systems that divert wash-water and waste directly to drainage ways or streams.

Table 3.10 Average percentage of collected livestock waste applied throughout year.

Month	Applied % of Total Beef	Land use
January	4.00	Cropland
February	4.00	Cropland
March	12.00	Cropland
April	12.00	Cropland
May	12.00	Cropland
June	8.00	Pasture
July	8.00	Pasture
August	8.00	Pasture
September	12.00	Cropland
October	12.00	Cropland
November	4.00	Cropland
December	4.00	Cropland

Some livestock were expected to deposit a portion of waste on land areas. The percentage of time spent on pasture for dairy and beef cattle was estimated based on projects in other areas of southwest Virginia. Horses were assumed to be in pasture 100% of the time with no access to streams.

It was assumed that beef cattle were expected to make a contribution through direct deposition with access to flowing water. For areas where direct deposition by cattle is assumed, the average amount of time spent by dairy and beef cattle in stream access areas for each month is given in **Table 3.11** and **Table 3.12**.

Table 3.11 Average time dry cows and replacement heifers spend in different areas per day.

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	23.3	0.7	0
February	23.3	0.7	0
March	22.6	1.4	0
April	21.8	2.2	0
May	21.8	2.2	0
June	21.1	2.9	0
July	21.1	2.9	0
August	21.1	2.9	0
September	21.8	2.2	0
October	22.6	1.4	0
November	22.6	1.4	0
December	23.3	0.7	0

Table 3.12 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day.

Month	Pasture (hr)	Stream Access (hr)
January	23.3	0.7
February	23.3	0.7
March	23.0	1.0
April	22.6	1.4
May	22.6	1.4
June	22.3	1.7
July	22.3	1.7
August	22.3	1.7
September	22.6	1.4
October	23.0	1.0
November	23.0	1.0
December	23.3	0.7

3.2.5 Wildlife

The predominant wildlife species in the study area were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), citizens from the watershed, and source sampling. Population densities were calculated from data provided by VDGIF and FWS, and are listed in **Table 3.13** (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987). Although additional species exist in the watershed, population and fecal production data are limited in regard to many species. However, the predominant wildlife species contributing fecal bacteria have been represented based on the best available data.

The numbers of animals estimated to be in the study area are reported in **Table 3.14**. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996, and Yagow, 1999b). The densities shown in **Table 3.13** are the final densities used after adjustments made as a result of discussions at the first public meeting. The Populations shown in **Table 3.14** reflect those changes.

Table 3.13 Wildlife population densities for the study area.

Deer (an/ac of habitat)	Turkey (an/ac of habitat)	Beaver (an/stream mile)	Goose (an/ac of habitat)	Duck (an/ac of habitat)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Nutria (adult) (an/1,000 foot of shoreline)	Nutria (youth) (an/1,000 foot of shoreline)
0.03439	0.00907	0.00907	0.006394	0.013031	0.15627	0.07034	3.5	12.5

Table 3.14 Estimated wildlife populations in the study area.[1]

Sub-watershed	Impairment Group	Deer	Turkey	Beaver	Goose	Duck	Muskrat	Raccoon	Nutria (adult)	Nutria (youth)
1	North Landing River	228	53	100	17	34	409	188	371	1,326
2	North Landing River	196	31	203	30	61	734	285	213	760
3	North Landing River	801	164	413	71	145	1,742	841	341	1,217
4	Pocaty River	694	98	440	67	137	1,643	637	453	1,619
5	Muddy Creek/Ashville Bridge Creek	29	6	17	3	6	71	27	42	150
6	Beggars Bridge Creek	113	18	69	11	22	268	104	32	116
7	Muddy Creek/Ashville Bridge Creek	97	14	67	10	20	245	92	0	0
8	Muddy Creek/Ashville Bridge Creek	83	13	57	9	18	218	82	52	187
9	Hell Point Creek	32	8	15	3	5	65	29	73	262
10	Hell Point Creek	20	5	13	2	4	53	21	56	198
11	Hell Point Creek	223	45	166	27	55	656	287	267	954
Total	**Total**	2,516	455	1,560	250	507	6,104	2,593	1,900	6,789

[1] .. These are the predominant, fecal coliform-producing species in the watershed and those for which dependable fecal coliform loads are available. Other species of fox, coyotes, and otter are also found in the watershed, however confident population densities are not currently available.

Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 100 feet of stream) are reported in **Table 3.15**.

Table 3.15 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Deer	380,000	5
Turkey	1,332	5
Beaver	1,000	100
Goose	250,000	50
Duck	3,500	75
Muskrat	1,900,000	90
Raccoon	2,100,000	5
Nutria (adult)	1,900,000	90
Nutria (youth)	1,900,000	90

Table 3.16 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife scat performed by MapTech. The only value that was not obtained from MapTech sampling was for beaver.

Table 3.16 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	**Primary** = region within 600 ft of perennial streams **Secondary** = region between 601 and 7,920 ft from perennial streams **Infrequent/Seldom** = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	100	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Beaver	200	**Primary** = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) **Infrequent/Seldom** = rest of the watershed area
Nutria (adult)[1]	150	**Primary** = Shorelines
Nutria (youth)[1]	75	**Primary** = Shorelines
Deer	772	**Primary** = forested, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, wetlands, transitional land **Secondary** = low density residential, medium density residential **Infrequent/Seldom** = remaining land use areas
Turkey[2]	320	**Primary** = forested, harvested forest land, grazed woodland, orchards, wetlands, transitional land **Secondar**y = cropland, pasture **Infrequent/Seldom** = remaining land use areas
Goose[3]	225	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Mallard (Duck)	150	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area

[1] Nutria waste load was calculated as midpoint between beavers and muskrats based on animal size. Youth nutria waste production was assumed to be half of adult nutria.
[2] Waste load for domestic turkey (ASAE, 1998).
[3] Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003).

4. BACTERIA MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

This chapter represents a brief description of the modeling procedures. A complete description is presented in **Appendix B**. Computer modeling was used in this study as a tool to allow simulating the interaction between the land surface and subsurface and the quantities and fate of various bacteria sources by location. The model allows the climatological factors and in particular, precipitation, to drive this interaction. By modeling the watershed conditions and bacteria sources, the model allows quantifying the relationship between sources as they exist throughout the watershed to bacteria concentrations within the watershed streams. Two modeling approaches were used in the analysis. For the free flowing tributaries, the model used was the USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources.

For the tidally influenced subwatersheds, the Steady State Tidal Prism Model, which is used by VADEQ for modeling tidally impacted waterbodies, was implemented within the HSPF framework to model the tidally influenced segments in conjunction with lateral free-flowing creeks.

To adequately represent the spatial variation in the watershed parameters and pollutant quantification, the drainage area was divided into eleven (11) subwatersheds (**Figure 3.1**). Hydrologic parameters collected for the watershed were adjusted based on previously conducted hydrologic calibration in nearby projects where flow was calibrated by comparing model output to observed flow.

Once the flow component was built, quantified bacteria sources were entered into the model and a simulated bacteria concentration was generated for each subwatershed. The simulated bacteria concentration was calibrated by comparing model simulations of bacteria to observed bacteria values collected by VADEQ at multiple locations. Finally the bacteria concentration was validated using a different time period from the calibration period.

Existing conditions of bacteria were then entered into the model to simulate the baseline conditions. This stage gives an indication of the current predicted violation rates of the geometric mean standard. The model was then used in the allocation process where reductions are simulated for various sources until the bacteria geometric mean standard was met. A complete description of the modeling approach is presented in **Appendix B**.

5. BACTERIAL ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, permitted sources) and load allocations (LAs, non-permitted sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (*e.g*., accuracy of wildlife populations). The definition is typically denoted by the expression:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS}$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For these impairments, the TMDLs are expressed in terms of colony forming units (or resulting concentration).

For bacteria, water quality monitoring represents existing conditions which are the sum of anthropogenic and natural background pollutants. Water quality modeling mimics the sum condition. Nevertheless, because wildlife represents the major source of natural background bacteria pollution, it was separately quantified and assigned a load. In the final TMDL equation, the natural background contributions are included in the LA component.

Allocation scenarios were modeled using the HSPF model. Scenarios were created by reducing direct and land-based bacteria until the water quality standards were attained. The TMDLs developed for the impairments in the study area were based on the *E. coli* riverine Virginia State standards and *enterococci* transitional water Virginia State standards, depending on impairment. As detailed in Section 2.1, the VADEQ riverine primary contact recreational use *E. coli* standards state that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 mL and *enterococci* geometric mean standard is 35 cfu/100 mL.

According to the guidelines put forth by the VADEQ (VADEQ, 2003a) for modeling bacteria with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a data set containing 493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc}) \qquad \textit{E.coli}$$

$$\log_2(C_{ent}) = 1.2375 + 0.59984 \cdot \log_2(C_{fc}) \qquad \textit{Enterococci}$$

where C_{ec} is the concentration of *E. coli* in cfu/100 mL, C_{ent} is the concentration of *enterococci* in cfu/100 mL, and C_{fc} is the concentration of fecal coliform in cfu/100 mL.

Pollutant concentrations were modeled over the entire duration of a representative modeling period and pollutant loads were adjusted until the standards were met. The development of the allocation scenarios was an iterative process that required many runs with each followed by an assessment of load reduction against the applicable water quality standards. Allocation was conducted in a way where simulated concentrations from all subwatersheds that include an impaired segment as well as the output subwatershed met the standard.

5.1 Margin of Safety (MOS)

In order to account for uncertainty in modeled output, a Margin of Safety (MOS) was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. A MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of an MOS in the development of bacteria TMDLs is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of these TMDLs. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will in fact succeed in meeting the water quality standard. Examples of the implicit MOS used in the development of these TMDLs are:

- Allocating permitted point sources at the maximum allowable fecal coliform concentration,
- Selecting a modeling period that represented the critical hydrologic conditions in the watershed, and

- Modeling all outflow from straight pipes and failing septic systems at the human waste concentration including the gray-water portion.

5.2 Waste Load Allocations (WLAs)

There is one individual VPDES point source currently permitted to discharge bacteria into the study area along with three single family home permitted sources. The allocation for this discharge is equivalent to its current permit levels (design discharge and 126 cfu/100 mL for *E.coli* or 35 cfu/100 mL for *enterococci*). Future growth was accounted for by setting aside 1% of the TMDL for growth in the permitted discharge or creation of new ones. There are two Municipal Separate Storm Sewer System (MS4) permits in the study area which are noted in **Table 3.3**.

5.3 Load Allocations (LAs)

Load allocations to nonpoint sources are divided into land-based loadings from land uses (nonpoint source, NPS) and directly applied loads in the stream (livestock, wildlife, and straight pipes). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads most significantly impact bacteria concentrations during high flow conditions, while direct deposition NPS most significantly impact low flow bacteria concentrations. Nonpoint source load reductions were performed by land use, as opposed to reducing sources, as it is considered that the majority of BMPs will be implemented by land use. Reductions to direct non-point sources were performed by source. **Appendix C** shows tables of the breakdown of the annual fecal coliform per animal per land use for contributing subwatersheds to each impairment.

5.4 Final Total Maximum Daily Loads (TMDLs)

Virginia's water quality standard does not permit any exceedances, therefore, modeling was conducted for a target value of 0% exceedance of the VADEQ primary contact recreational use (swimming) 30-day geometric mean standard (126 cfu/100mL geometric mean for *E. coli* in riverine segments, and 35 cfu/100 mL geometric mean for *enterococci* in estuarine segments). Allocation scenarios were run for all subwatersheds until all simulated bacteria concentrations at the outlet of all impaired subwatershed were allocated to 0% exceedances.

The first table in each of the following five sections represents the scenarios developed to determine the TMDLs. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed.

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. In each table, a scenario reflects the impact of eliminating direct human sources from straight pipes leading to the final allocation scenario that contains the predicted reductions needed to meet 0% exceedance of all applicable water quality standards. The graphs in the following sections depict the existing and allocated 30-day geometric mean in-stream bacteria concentrations.

The second table in each of the following sections shows the existing and allocated bacteria loads. The third table shows the final annual in-stream allocated loads for the appropriate bacteria species. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. The final table is an estimation of the in-stream daily load of bacteria.

5.4.1 North Landing River

Table 5.1 shows allocation scenarios used to determine the final TMDL for the North Landing River watershed which includes subwatersheds 1, 2, and 3. This watershed includes one impaired segment on North Landing River (VAT-K41R_NLR03A06). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean *E. coli* standard (126 cfu/100 mL geometric mean). The existing condition, Scenario 0, shows a violation of the geometric mean standard. Scenarios 1 (eliminating straight pipe inputs) and scenario 2 (eliminating direct livestock contribution) show improvement in water quality but not enough to meet the water quality standard. Scenarios 3 through 5 explore the impact of eliminating land based anthropogenic sources but even scenario 5 which calls for eliminating almost all anthropogenic impact is not enough to meet the standard.

Scenario 6 calls for eliminating the impact from wildlife by 50% and does meet the water quality standard and, therefore, is selected as the final TMDL scenario.

Table 5.1 Allocation scenarios for reducing current bacteria loads in the North Landing River.

		Wildlife Land Based		Ag. Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations (> 126 GM)
Scenario	**Wildlife Direct**	**Forest, Wetlands, Barren[1], Comm., open space**	**Livestock Direct**	**Cropland, Pasture, LAX[2]**	**Straight Pipes**	**Residential**	**sub01 (%)**
0	0	0	0	0	0	0	48.89%
1	0	0	0	0	100	0	30.85%
2	0	0	100	0	100	0	29.57%
3	0	0	100	0	100	50	19.82%
4	0	0	100	50	100	50	18.10%
5	0	0	100	99	100	99	3.51%
6[3]	50	50	100	99	100	99	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]LAX - livestock pasture access near flowing streams.
[3]Final TMDL scenario.

Figure 5.1 shows the existing and allocated monthly geometric mean *E. coli* concentrations at the most limiting subwatershed outlet (subwatershed 1). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

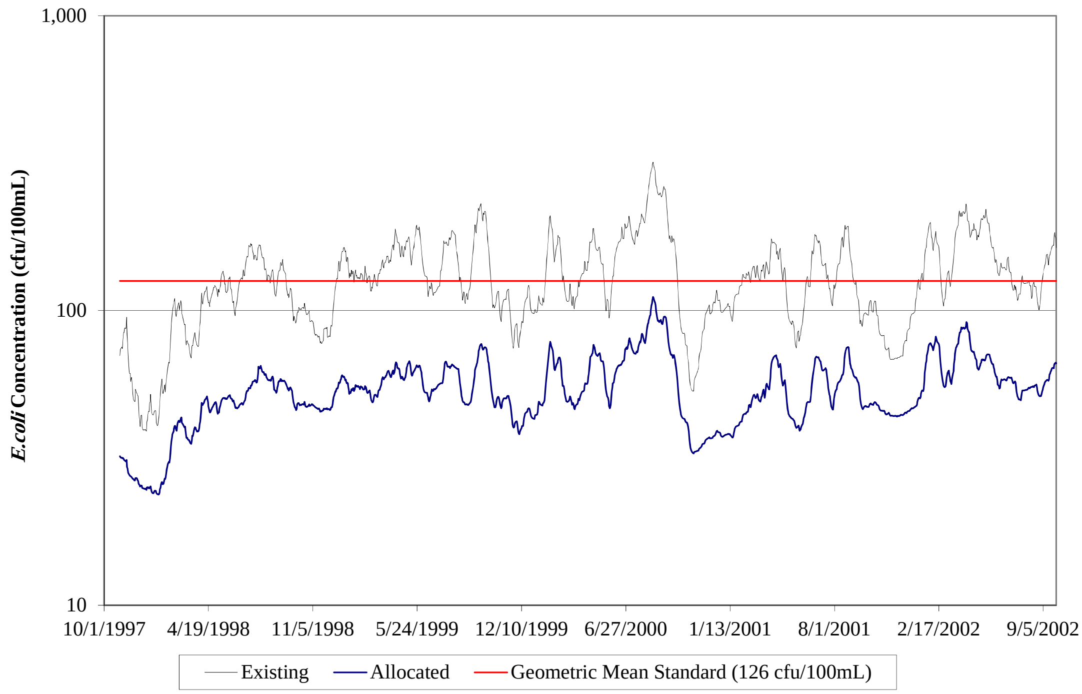

Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 1.

Table 5.2 contains estimates of existing and allocated in-stream *E. coli* loads at the outlet of North Landing River within the study area (at approximately river mile 10.25). The estimates in this table are reported as average annual cfu per year and are generated from available data. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Table C. 1 and **Table C. 11** in **Appendix C** include the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation. **Table C. 6** and **Table C. 16** detail the direct deposition fecal coliform load.

Table 5.2 Estimated existing and allocated *E. coli* in-stream loads at the outlet of subwatershed 1 in the North Landing River study area.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	Residential	1.22E+15	1.22E+13	99.0%
	Cropland	6.04E+13	6.04E+11	99.0%
	Forest	4.16E+13	2.08E+13	50.0%
	Pasture/Hay	3.11E+14	3.11E+12	99.0%
	Commercial	2.28E+12	1.14E+12	50.0%
	LAX*	1.29E+13	1.29E+11	99.0%
	Open Space	8.65E+13	4.33E+13	50.0%
	Wetland	1.67E+14	8.33E+13	50.0%
	Barren	1.26E+12	6.28E+11	50.0%
Direct				
	Human	1.57E+13	0.00E+00	100.0%
	Livestock	1.11E+12	0.00E+00	100.0%
	Wildlife	1.45E+13	7.26E+12	50.0%
	Permitted Sources	2.18E+09	2.18E+09	0%
	Virginia Beach and VDOT MS4	3.86E+13	2.32E+12	94%
	Chesapeake and VDOT MS4	3.57E+13	2.14E+12	94%
Future Growth	Future Growth	0.00E+00	1.79E+12	NA
Total Loads		2.01E+15	1.79E+14	91.1%

*: LAX - livestock pasture access near flowing streams.

Table 5.3 shows the annual TMDL, which gives the amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off (except for permitted point sources) and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework.

Multiple Municipal Storm Sewer System (MS4) permits exist within the study area. In most cases, MS4 areas are overlapping or intertwined and there is currently no standardized technology for disaggregating the MS4 loads to assign individual Waste Load Allocations. EPA and VADEQ support the aggregation of MS4 WLAs for this reason on a county/city level. Additionally, aggregation encourages stakeholder cooperation and speeds the implementation of appropriate BMPs to address reductions required by the TMDLs. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.3 Final annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation at the outlet of subwatershed 1 on the North Landing River.

Impairment	WLA[1]	LA	MOS	TMDL
North Landing River	6.25E+12	1.73E+14	*Implicit*	1.79E+14
VAG403048	*8.71E+08*			
VAG403053	*1.31E+09*			
Virginia Beach and VDOT MS4[2]	*2.32E+12*			
Chesapeake and VDOT MS4[2]	*2.14E+12*			
Future Load	*1.79E+12*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily in-stream loads of the North Landing River are shown in **Table 5.4**. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. The daily WLA, including that of future load, is calculated as the annual WLA divided by 365.25. Daily load allocation is calculated as the difference between the daily TMDL and daily WLA. Load allocation is calculated as the difference between the daily TMDL and daily WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.4 Final daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation at the outlet of subwatershed 1 on the North Landing River.

Impairment	WLA[1]	LA	MOS	TMDL[2]
North Landing River	1.71E+10	5.74E+12	*Implicit*	5.76E+12
VAG403048	2.38E+06			
VAG403053	3.58E+06			
Virginia Beach and VDOT MS4	6.35E+09			
Chesapeake and VDOT MS4	5.86E+09			
Future Load	4.90E+09			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.2 Pocaty River

Table 5.5 shows allocation scenarios used to determine the final TMDL for the Pocaty River watershed which includes subwatershed 4. This watershed includes one impaired segment on Pocaty River (VAT-K41R_PCT01A02). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational use (swimming) 30-day geometric mean *E. coli* standard (126 cfu/100 mL geometric mean). The existing condition, Scenario 0, shows a violation of the geometric mean standard. Scenarios 1 (eliminating straight pipe inputs) and scenario 2 (eliminating direct livestock contribution) show improvement in water quality but not enough to meet the water quality standard. Scenarios 3 through 5 explore the impact of eliminating land based anthropogenic sources. Scenario 5 meets the water quality standard and therefore, is selected as the final TMDL scenario.

Table 5.5 Allocation scenarios for reducing current bacteria loads in the Pocaty River.

		Wildlife Land Based		Ag. Land Based	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations (> 126 GM)
							sub04
Scenario	Wildlife Direct	Forest, Wetlands, Barren[1], Comm., open space	Livestock Direct	Cropland, Pasture, LAX[2]	Straight Pipes	Residential	(%)
0	0	0	0	0	0	0	22.27%
1	0	0	0	0	100	0	15.92%
2	0	0	100	0	100	0	12.36%
3	0	0	100	0	100	50	11.19%
4	0	0	100	50	100	50	4.45%
5[3]	0	0	100	99	100	99	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]LAX - livestock pasture access near flowing streams.
[3]Final TMDL Scenario

Figure 5.2 shows the existing and allocated monthly geometric mean *E. coli* concentrations at the most limiting subwatershed outlet (subwatershed 4). The graph shows existing conditions in black, with allocated conditions overlaid in blue.

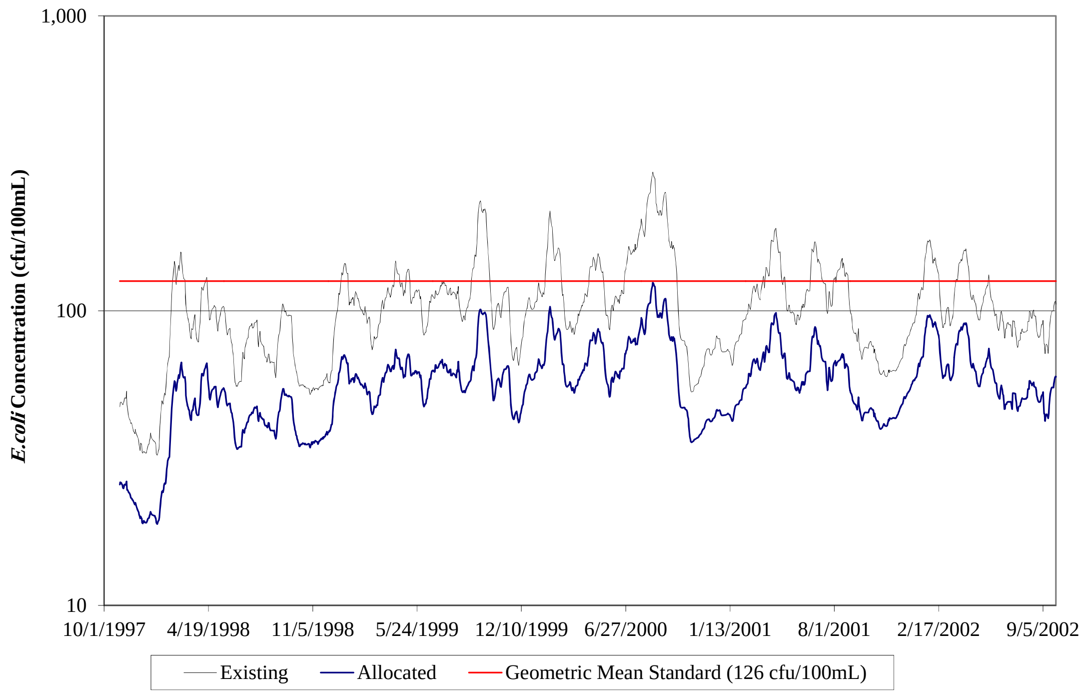

Figure 5.2 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 4.

Table 5.6 contains estimates of existing and allocated in-stream *E. coli* loads at the outlet of Pocaty River. The estimates in this table are reported as annual cfu per year and are generated from available data. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

Table C. 2 and **Table C. 12** in **Appendix C** include the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation. **Table C. 7** and **Table C. 17** detail the direct deposition fecal coliform loads.

Table 5.6 Estimated existing and allocated *E. coli* in-stream loads at the outlet of subwatershed 4 in the Pocaty River study area.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	Residential	9.30E+13	9.30E+11	99.0%
	Cropland	2.63E+14	2.63E+12	99.0%
	Forest	4.56E+13	2.28E+13	50.0%
	Pasture/Hay	1.88E+15	1.88E+13	99.0%
	Commercial	2.07E+11	1.03E+11	50.0%
	**LAX	7.66E+13	7.66E+11	99.0%
	Open Space	2.94E+13	1.47E+13	50.0%
	Wetland	1.06E+14	5.32E+13	50.0%
	*Barren	1.04E+12	5.18E+11	50.0%
Direct				
	Human	1.30E+13	0.00E+00	100.0%
	Livestock	7.31E+12	0.00E+00	100.0%
	Wildlife	1.59E+13	7.93E+12	50.0%
	Permitted Sources	1.65E+09	1.65E+09	0%
	Virginia Beach and VDOT MS4	1.01E+13	1.31E+12	87%
	Chesapeake and VDOT MS4	2.06E+11	2.68E+10	87%
Future Growth	Future Growth	0.00E+00	2.62E+11	NA
Total Loads		2.54E+15	1.24E+14	95.1%

* Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
**LAX - livestock pasture access near flowing streams.

Table 5.7 shows the annual TMDL, which gives the amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off (except for permitted point sources) and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework.

Multiple Municipal Storm Sewer System (MS4) permits exist within the study area. In most cases, MS4 areas are overlapping or intertwined and there is currently no standardized technology for disaggregating the MS4 loads to assign individual Waste

Load Allocations. USEPA and VADEQ support the aggregation of MS4 WLAs for this reason on a county/city level. Additionally, aggregation encourages stakeholder cooperation and speeds the implementation of appropriate BMPs to address reductions required by the TMDLs. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.7 Final annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation at the outlet of subwatershed 4 on the Pocaty River.

Impairment	WLA[1]	LA	MOS	TMDL
Pocaty River	2.58E+12	1.21E+14	*Implicit*	1.24E+14
VAG403065	*1.65E+09*			
Virginia Beach and VDOT MS4[2]	*1.31E+12*			
Chesapeake and VDOT MS4[2]	*2.68E+10*			
Future Load	*1.24E+12*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily in-stream loads of the Pocaty River are shown in **Table 5.8**. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. The daily WLA, including that of future load, is calculated as the annual WLA divided by 365.25. Daily load allocation is calculated as the difference between the daily TMDL and daily WLA. Load allocation is calculated as the difference between the daily TMDL and daily

WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.8 Final daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation at the outlet of subwatershed 4 on the Pocaty River.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Pocaty River	7.06E+09	1.42E+12	*Implicit*	1.43E+12
VAG403065	4.53E+06			
Virginia Beach and VDOT MS4	3.59E+09			
Chesapeake and VDOT MS4	7.34E+07			
Future Load	3.394E+09			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.3 Beggars Bridge Creek

Table 5.9 shows allocation scenarios used to determine the final TMDL for Beggars Bridge Creek watershed which includes subwatershed 6. This watershed includes one impaired segment on Beggars Bridge Creek (VAT-K42E_BBC01A04). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ estuarine primary contact recreational use (swimming) 30-day geometric mean *enterococci* standard (35 cfu/100 mL geometric mean). The existing condition, Scenario 0, shows a violation of the geometric mean standard. Scenarios 1 (eliminating straight pipe inputs) and scenario 2 (eliminating direct livestock contribution) show improvement in water quality but not enough to meet the water quality standard. Scenarios 3 through 5 explore the impact of eliminating land based anthropogenic sources but even scenario 5 which calls for eliminating almost all anthropogenic impact is not enough to meet the standard.

Scenario 7 calls for eliminating the impact from wildlife by 90% and does meet the water quality standard and, therefore, is selected as the final TMDL scenario.

Table 5.9 Allocation scenarios for reducing current bacteria loads in Beggars Bridge Creek (subwatershed 6).

		Wildlife Land Based		**Ag. Land Based**	**Human Direct**	**Human and Pet Land Based**	**VADEQ *enterococci* Standard percent violations (> 35 GM)**
Scenario	**Wildlife Direct**	**Forest, Wetlands, Barren[1], Comm., open space**	**Livestock Direct**	**Cropland, Pasture, LAX[2]**	**Straight Pipes**	**Residential**	**sub06 (%)**
0	0	0	0	0	0	0	87.92%
1	0	0	0	0	100	0	74.44%
2	0	0	100	0	100	0	74.05%
3	0	0	100	0	100	50	72.16%
4	0	0	100	50	100	50	67.43%
5	0	0	100	99	100	99	55.07%
6	50	50	100	99	100	99	17.87%
7[3]	90	90	100	99	100	99	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]LAX - livestock pasture access near flowing streams.
[3]Final TMDL Scenario

Figure 5.3 shows the existing and allocated monthly geometric mean *enterococci* concentrations at subwatershed 6. The graph shows existing conditions in black, with allocated conditions overlaid in blue.

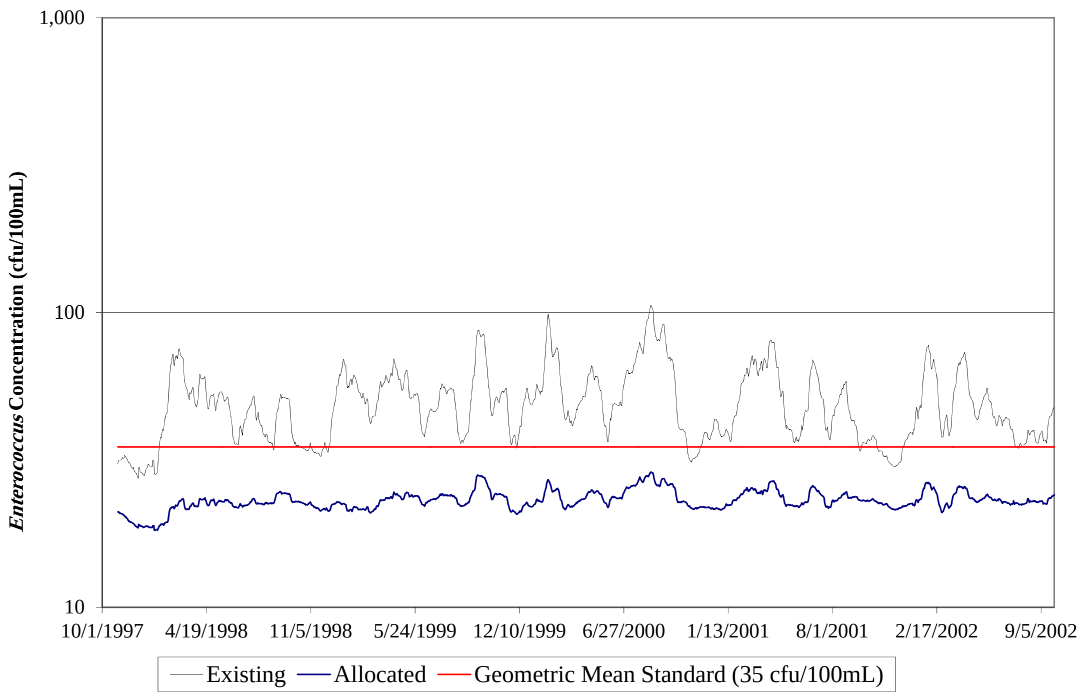

Figure 5.3 Existing and allocated monthly geometric mean in-stream *enterococci* concentrations in subwatershed 6.

Table 5.10 contains estimates of existing and allocated in-stream *enterococci* loads at the outlet of Beggars Bridge Creek. The estimates in this table are reported as annual cfu per year and are generated from available data. The percent reductions needed to meet zero percent violations of the 35 cfu/100mL geometric mean standard are given in the final column.

Table C. 3 and **Table C. 13** in **Appendix C** include the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation. **Table C. 8** and **Table C. 13** detail the direct deposition fecal coliform loads.

Table 5.10 Estimated existing and allocated *enterococci* in-stream loads at the outlet of subwatershed 6 in Beggars Bridge Creek study area.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	Residential	4.49E+13	4.49E+11	99.0%
	Cropland	1.50E+14	1.50E+12	99.0%
	Forest	1.82E+13	1.82E+12	90.0%
	Pasture/Hay	9.28E+14	9.28E+12	99.0%
	Commercial	0.00E+00	0.00E+00	--
	**LAX	6.48E+12	6.48E+10	99.0%
	Open Space	9.13E+12	9.13E+11	90.0%
	Wetland	1.08E+14	1.08E+13	90.0%
	*Barren	0.00E+00	0.00E+00	--
Direct				
	Human	4.76E+12	0.00E+00	100.0%
	Livestock	1.49E+11	0.00E+00	100.0%
	Wildlife	6.83E+12	6.83E+11	90.0%
	Permitted Sources	--	--	--
	Virginia Beach and VDOT MS4	1.39E+13	4.17E+11	97%
Future Growth	Future Growth	0.00E+00	2.62E+11	NA
Total Loads		1.29E+15	2.62E+13	98.0%

* Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
**LAX - livestock pasture access near flowing streams.

Table 5.11 shows the annual TMDL, which gives the amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off (except for permitted point sources) and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework.

Multiple Municipal Storm Sewer System (MS4) permits exist within the study area. In most cases, MS4 areas are overlapping or intertwined and there is currently no standardized technology for disaggregating the MS4 loads to assign individual Waste Load Allocations. USEPA and VADEQ, and DCR support the aggregation of MS4

WLAs for this reason on a county/city level. Additionally, aggregation encourages stakeholder cooperation and speeds the implementation of appropriate BMPs to address reductions required by the TMDLs. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.11 Final annual in-stream *enterococci* bacterial loads (cfu/year) modeled after TMDL allocation at the outlet of subwatershed 6 on Beggars Bridge Creek.

Impairment	WLA[1]	LA	MOS	TMDL
Beggars Bridge Creek	6.79E+11	2.55E+13	*Implicit*	2.62E+13
Virginia Beach and VDOT MS4[2]	*4.17E+11*			
Future Load	*2.62E+11*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily in-stream loads of the Beggars Bridge Creek are shown in **Table 5.12**. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 104 cfu/100ml. The daily WLA, including that of future load, is calculated as the annual WLA divided by 365.25. Daily load allocation is calculated as the difference between the daily TMDL and daily WLA. Load allocation is calculated as the difference between the daily TMDL and daily WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.12 Final daily in-stream *enterococci* bacterial loads (cfu/day) modeled after TMDL allocation at the outlet of subwatershed 6 on Beggars Bridge Creek.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Beggars Bridge	1.86E+09	7.76E+11	*Implicit*	7.78E+11
Virginia Beach and VDOT MS4	1.14E+09			
Future Load	7.17E+08			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 104 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.4 Muddy Creek / Ashville Bridge Creek

Table 5.13 shows allocation scenarios used to determine the final TMDL for Muddy Creek / Ashville Bridge Creek watershed which includes subwatersheds 5, 7, and 8. This watershed includes two impaired segments on Muddy Creek (VAT-K42E_MDY01A04) and Ashville Bridge Creek (VAT-K42E_ASH01A06). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ estuarine primary contact recreational use (swimming) 30-day geometric mean *enterococci* standard (35 cfu/100 mL geometric mean). The existing condition, Scenario 0, shows a violation of the geometric mean standard. Scenarios 1 (eliminating straight pipe inputs) and scenario 2 (eliminating direct livestock contribution) show improvement in water quality but not enough to meet the water quality standard. Scenarios 3 through 5 explore the impact of eliminating land based anthropogenic sources but even scenario 5 which calls for eliminating almost all anthropogenic impact is not enough to meet the standard. Scenario 7 calls for eliminating the impact from wildlife by 90% and does meet the water quality standard and therefore, is selected as the final TMDL scenario.

Table 5.13 Allocation scenarios for reducing current bacteria loads in Ashville Bridge Creek / Muddy Creek.

Scenario	Wildlife Direct	Wildlife Land Based: Forest, Wetlands, Barren[1], Comm., open space	Livestock Direct	Ag. Land Based: Cropland, Pasture, LAX[2]	Human Direct: Straight Pipes	Human and Pet Land Based: Residential	VADEQ *enterococci* Standard percent violations (> 35 GM): sub05 (Muddy Cr.) (%)	VADEQ *enterococci* Standard percent violations (> 35 GM): sub08 (Ashville Bridge Cr.) (%)
0	0	0	0	0	0	0	87.42%	94.49%
1	0	0	0	0	100	0	79.29%	91.26%
2	0	0	100	0	100	0	79.01%	91.20%
3	0	0	100	0	100	50	75.06%	89.70%
4	0	0	100	50	100	50	70.77%	87.58%
5	0	0	100	99	100	99	52.84%	74.94%
6	50	50	100	99	100	99	16.09%	41.98%
7[3]	90	90	100	99	100	99	0.00%	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]LAX - livestock pasture access near flowing streams.
[3]Final TMDL Scenario

Figure 5.4 and **Figure 5.5** show the existing and allocated monthly geometric mean *enterococci* concentrations at the subwatershed 5 for Muddy Creek and subwatershed 8 for Ashville Bridge Creek, respectively. The graphs shows existing conditions in black, with allocated conditions overlaid in blue.

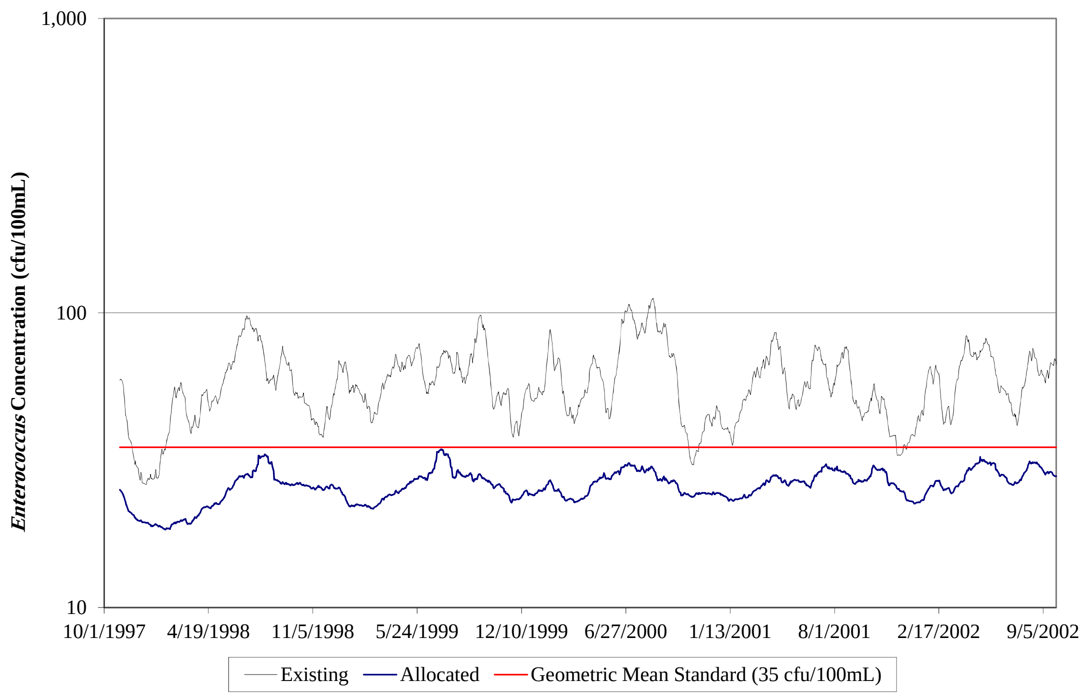

Figure 5.4 **Existing and allocated monthly geometric mean in-stream *enterococci* concentrations in subwatershed 8 (Ashville Bridge Creek).**

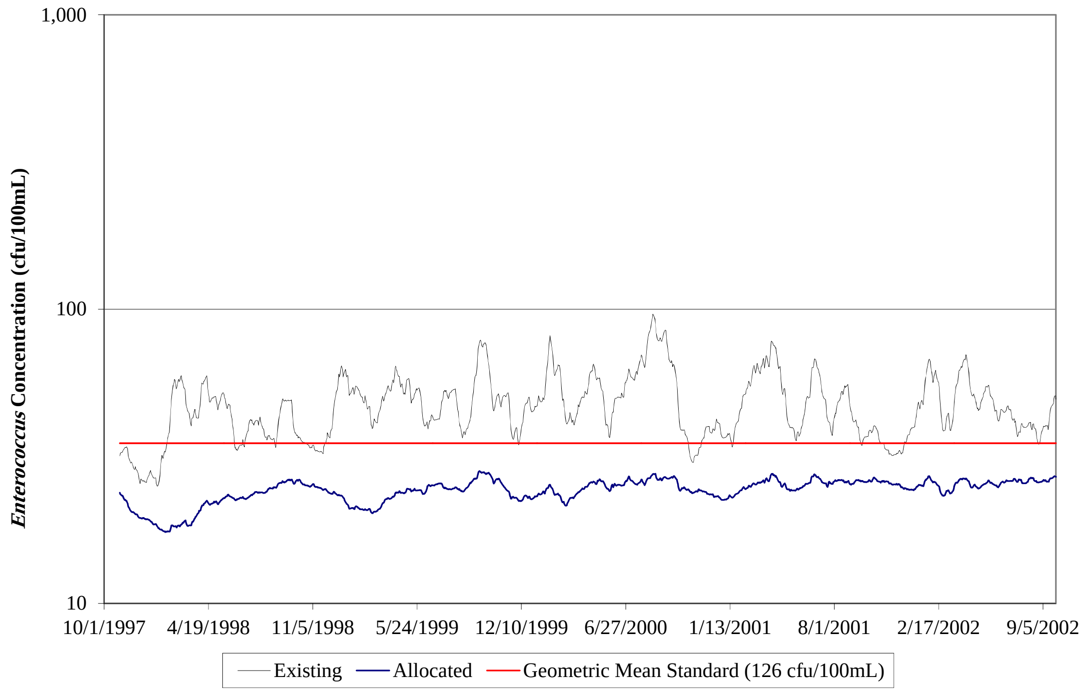

Figure 5.5 Existing and allocated monthly geometric mean in-stream *enterococci* concentrations in subwatershed 5 (Muddy Creek).

Table 5.14 contains estimates of existing and allocated in-stream *enterococci* loads at the outlet of Muddy Creek which also contains the Ashville Bridge Creek drainage area. The estimates in this table are reported as annual cfu per year and are generated from available data. The percent reductions needed to meet zero percent violations of the 35 cfu/100mL geometric mean standard are given in the final column.

Table C. 4 and **Table C. 14** in Appendix C include the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation. **Table C. 9** and **Table C. 19** detail the direct deposition fecal coliform loads.

Table 5.14 Estimated existing and allocated *enterococci* in-stream loads at the outlet of subwatershed 5 in Muddy Creek and Ashville Bridge Creek study area.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	Residential	9.95E+13	9.95E+11	99.0%
	Cropland	1.74E+14	1.74E+12	99.0%
	Forest	3.06E+13	3.06E+12	90.0%
	Pasture/Hay	1.69E+14	1.69E+12	99.0%
	Commercial	0.00E+00	0.00E+00	--
	**LAX	8.10E+12	8.10E+10	99.0%
	Open Space	1.75E+13	1.75E+12	90.0%
	Wetland	1.12E+14	1.12E+13	90.0%
	*Barren	0.00E+00	0.00E+00	--
Direct				
	Human	6.94E+12	0.00E+00	100.0%
	Livestock	1.73E+11	0.00E+00	100.0%
	Wildlife	9.65E+12	9.65E+11	90.0%
	Permitted Sources	--	--	--
	Virginia Beach and VDOT MS4	2.86E+13	5.72E+11	98%
Future Growth	Future Growth	0.00E+00	2.23E+11	NA
Total Loads		6.56E+14	2.23E+13	96.6%

* Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
**LAX - livestock pasture access near flowing streams.

Table 5.15 shows the annual TMDL, which gives the amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off (except for permitted point sources) and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework.

Multiple Municipal Storm Sewer System (MS4) permits exist within the study area. In most cases, MS4 areas are overlapping or intertwined and there is currently no standardized technology for disaggregating the MS4 loads to assign individual Waste

Load Allocations. USEPA and DEQ support the aggregation of MS4 WLAs for this reason on county/city level. Additionally, aggregation encourages stakeholder cooperation and speeds the implementation of appropriate BMPs to address reductions required by the TMDLs. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.15 Final annual in-stream *enterococci* bacterial loads (cfu/year) modeled after TMDL allocation at the outlet of subwatershed 5 on Muddy Creek which also contains the drainage area of Ashville Bridge Creek.

Impairment	WLA[1]	LA	MOS	TMDL
Muddy Creek + Ashville Bridge Creek	7.95E+11	2.15E+13	*Implicit*	2.23E+13
Virginia Beach and VDOT MS4[2]	*5.72E+11*			
Future Load	*2.23E+11*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily in-stream loads of the Muddy Creek and Ashville Bridge Creek are shown in **Table 5.16**. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 104 cfu/100ml. The daily WLA, including that of future load, is calculated as the annual WLA divided by 365.25. Daily load allocation is calculated as the difference between the daily TMDL and daily WLA. Load allocation is calculated as the difference between the daily TMDL and daily WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.16 Final daily in-stream *enterococci* bacterial loads (cfu/day) modeled after TMDL allocation at the outlet of subwatershed on Muddy Creek (also includes the drainage area of Ashville Bridge Creek).

Impairment	WLA[1]	LA	MOS	TMDL
Muddy Creek + Ashville Bridge Creek	2.18E+09	9.94E+11	*Implicit*	9.96E+11
Virginia Beach and VDOT MS4[2]	1.57E+09			
Future Load	6.11E+08			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 104 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.5 Hell Point Creek (Upper + Lower)

Table 5.17 shows allocation scenarios used to determine the final TMDL for Hell Point Creek watershed which includes subwatersheds 9, 10, and 11. This watershed includes two impaired segments on Hell Point Creek: upper (VAT-K42E_HPC01A00) and lower (VAT-K42E_HPC02A04). Because Virginia's water quality standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ estuarine primary contact recreational use (swimming) 30-day geometric mean *enterococci* standard (35 cfu/100 mL geometric mean). The existing condition, Scenario 0, shows a violation of the geometric mean standard. Scenarios 1 (eliminating straight pipe inputs) and scenario 2 (eliminating direct livestock contribution) show improvement in water quality but not enough to meet the water quality standard. Scenarios 3 through 5 explore the impact of eliminating land based anthropogenic sources but even scenario 5 which calls for eliminating almost all anthropogenic impact is not enough to meet the standard. Scenarios 6 and 7 calls for eliminating the impact from wildlife by 50% and 90%, respectively and both meet the water quality standard and therefore. Scenario 7 is selected as the final TMDL scenario since allocation was conducted for all *enterococci* impairments using the nested approach (Ashville Bridge Creek was the limiting impairment).

Table 5.17 Allocation scenarios for reducing current bacteria loads in Hell Point Creek.

		Wildlife Land Based		Ag. Land Based	Human Direct	Human and Pet Land Based	VADEQ *enterococci* Standard percent violations (> 35 GM)	
Scenario	**Wildlife Direct**	**Forest, Wetlands, Barren[1], Comm., open space**	**Livestock Direct**	**Cropland, Pasture, LAX[2]**	**Straight Pipes**	**Residential**	**Sub10 (Hell Point Cr., Upper) (%)**	**Sub9 (Hell Point Cr., Lower) (%)**
0	0	0	0	0	0	0	100.00%	92.09%
1	0	0	0	0	100	0	33.96%	8.02%
2	0	0	100	0	100	0	33.85%	8.02%
3	0	0	100	0	100	50	11.86%	5.96%
4	0	0	100	50	100	50	11.75%	5.96%
5	0	0	100	99	100	99	0.89%	3.67%
6	50	50	100	99	100	99	0.00%	0.00%
7[3]	90	90	100	99	100	99	0.00%	0.00%

[1]Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
[2]LAX - livestock pasture access near flowing streams.
[3]Final TMDL Scenario

Figure 5.6 and **Figure 5.7** show the existing and allocated monthly geometric mean *enterococci* concentrations at the subwatershed 10 and 9, respectively. The graphs shows existing conditions in black, with allocated conditions overlaid in blue.

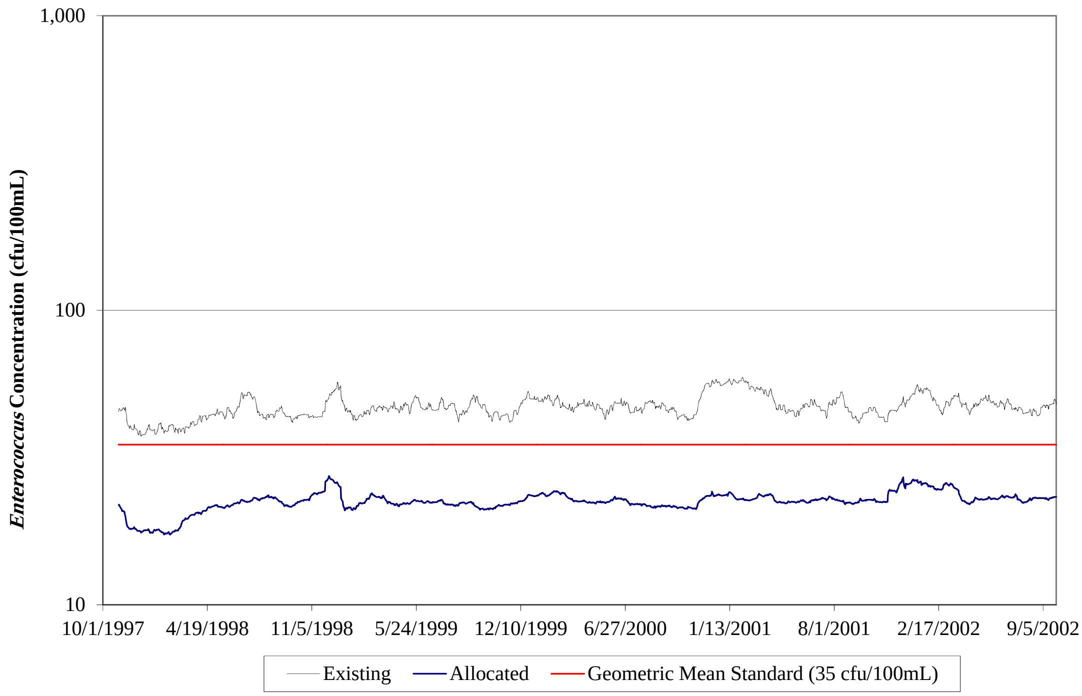

Figure 5.6 Existing and allocated monthly geometric mean in-stream *enterococci* concentrations in subwatershed 10 (Hell Point Creek, Upper).

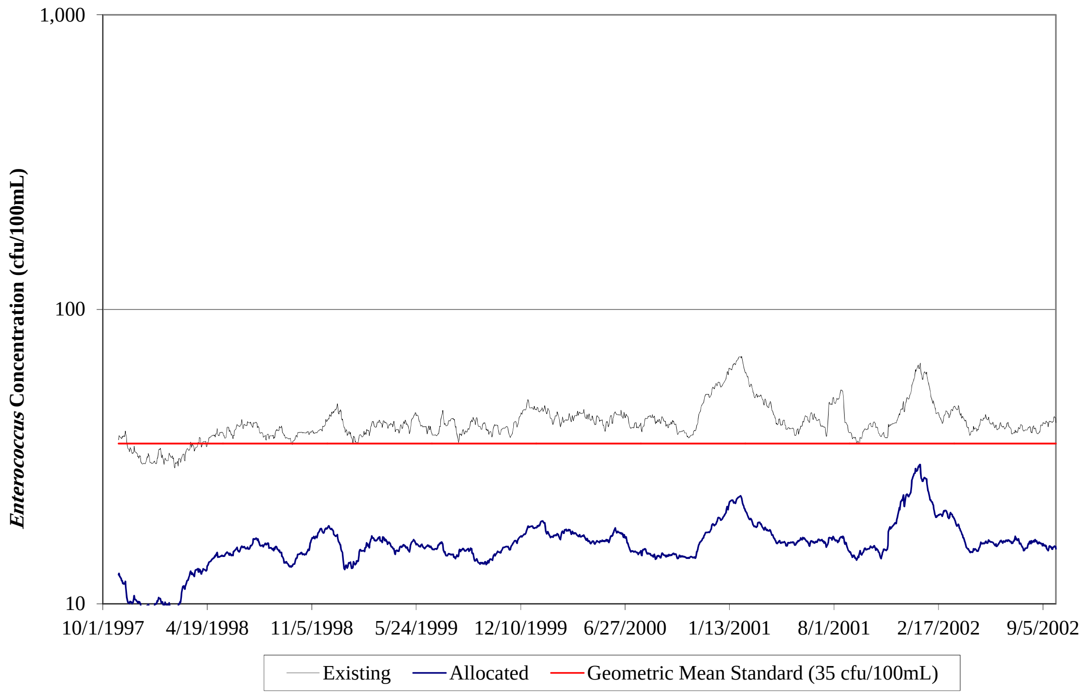

Figure 5.7 Existing and allocated monthly geometric mean in-stream *enterococci* concentrations in subwatershed 9 (Hell Point Creek, Lower).

Table 5.18 contains estimates of existing and allocated in-stream *enterococci* loads at the outlet of Hell Point Creek drainage area. The estimates in this table are reported as annual cfu per year and are generated from available data. The percent reductions needed to meet zero percent violations of the 35 cfu/100mL geometric mean standard are given in the final column.

Table C. 5 and **Table C. 15** in **Appendix C** include the land-based fecal coliform load distributions and offers more details for specific implementation development and source assessment evaluation. **Table C. 10** and **Table C. 20** detail the direct fecal coliform load.

Table 5.18 Estimated existing and allocated *enterococci* in-stream loads at the outlet of subwatershed 9 in Hell Point Creek (upper + lower) study area.

Source		Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based				
	Residential	6.03E+14	6.03E+12	99.0%
	Cropland	1.59E+13	1.59E+11	99.0%
	Forest	2.14E+13	2.14E+12	90.0%
	Pasture/Hay	2.71E+13	2.71E+11	99.0%
	Commercial	3.50E+12	3.50E+11	90.0%
	**LAX	1.67E+12	1.67E+10	99.0%
	Open Space	4.46E+13	4.46E+12	90.0%
	Wetland	1.20E+14	1.20E+13	90.0%
	*Barren	3.57E+11	3.57E+10	90.0%
Direct				
	Human	6.14E+12	0.00E+00	100.0%
	Livestock	3.19E+10	0.00E+00	100.0%
	Wildlife	1.17E+13	1.17E+12	90.0%
	Permitted Sources	1.84E+10	1.84E+10	0%
	Virginia Beach and VDOT MS4	8.69E+13	1.74E+12	98%
Future Growth	Future Growth	0.00E+00	2.87E+11	NA
Total Loads		9.42E+14	2.87E+13	97.0%

* Barren - Areas of bedrock, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
**LAX - livestock pasture access near flowing streams.

Table 5.19 shows the annual TMDL, which gives the amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off (except for permitted point sources) and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework.

A Multiple Municipal Storm Sewer System (MS4) permit exists within the study area. In most cases, MS4 areas are overlapping or intertwined and there is currently no standardized technology for disaggregating the MS4 loads to assign individual Waste

Load Allocations. USEPA and VADEQ support the aggregation of MS4 WLAs for this reason on county/city level. Additionally, aggregation encourages stakeholder cooperation and speeds the implementation of appropriate BMPs to address reductions required by the TMDLs. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.19 Final annual in-stream *enterococci* bacterial loads (cfu/year) modeled after TMDL allocation at the outlet of subwatershed 9 on Hell Point Creek (contains drainage area of both Hell Point Creek impairments).

Impairment	WLA[1]	LA	MOS	TMDL
Hell Point Creek (Upper + Lower)	2.04E+12	2.66E+13	*Implicit*	2.86E+13
VA0062391	*1.84E+10*			
Virginia Beach and VDOT MS4[2]	*1.74E+12*			
Future Load	*2.86E+11*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads of Hell Point Creek are shown in **Table 5.20**. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 104 cfu/100ml. The daily WLA, including that of future load, is calculated as the annual WLA divided by 365.25. Daily load allocation is calculated as the difference between the daily TMDL and daily WLA. Load allocation is calculated as the difference between the daily TMDL and daily WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.20 Final daily in-stream *enterococci* bacterial loads (cfu/day) modeled after TMDL allocation at the outlet of subwatershed 9 on Hell Point Creek.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Hell Point Creek (Upper + Lower)	5.59E+09	3.23E+12	*Implicit*	3.24E+12
VA0062391	5.04E+07			
Virginia Beach and VDOT MS4	4.76E+09			
Future Load	7.83E+08			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 104 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

6. PHOSPHORUS SOURCE ASSESSMENT

Nonpoint and point phosphorus sources were assessed for the impairments in the Pocaty River and Ashville Bridge Creek watersheds during the TMDL study. The source assessment component of the model is essential to allow for load allocation, the process by which acceptable loads of phosphorus are quantified. Phosphorus loadings from various land uses were obtained from the literature and best professional judgment.

6.1 Point Sources

The Virginia DEQ manages permitting point sources through a program called the Virginia Pollutant Discharge Elimination System (VPDES). There are currently no domestic permitted point sources in the Ashville Bridge Creek study area and only one domestic permit in the Pocaty River study area. Design flow for the domestic permit is 0.001 million gallons per day (MGD). In addition there are two municipal separate storm water sewer systems (MS4) permits in the study areas. Ashville Bridge Creek study area falls entirely within the Virginia Beach portion of the watershed while the Pocaty River study area is mostly within the Chesapeake portion of the watershed. The reference watershed contains no permitted facilities (MapTech, 2006).

6.2 Nonpoint Sources

Phosphorus loads from land surfaces reach water bodies through dissolved phase with runoff or groundwater, or through sediment transport during and following storm events. To quantify phosphorus loads reaching water bodies, sediment must also be quantified since sediment acts as a vehicle for phosphorus transport. Sediment parameters were identified in order to allow for estimating the sediment and phosphorus load reaching the water bodies. During runoff events (rainfall or irrigation), sediment is transported to streams from pervious land areas (*e.g.,* agricultural lands, urban areas). Rainfall energy, soil cover, soil characteristics, topography, and land management affect the magnitude of sediment loading.

Agricultural activities such as overgrazing, high tillage operations, livestock concentrations (*e.g.,* along stream edge, uncontrolled access to streams), forest harvesting, and land disturbance due to mining and construction (roads, buildings, etc.)

all accelerate erosion at varying degrees. During dry periods, sediment from air or traffic builds up on impervious areas and is transported to streams during runoff events. The magnitude of sediment loading from this source is affected by various factors (*e.g.*, the deposition from wind erosion and vehicular traffic). Phosphorus loading to water bodies is also controlled by the amount of runoff that reaches such water bodies since phosphorus can also move through the dissolved phase with water.

6.2.1 Agricultural Land

Agricultural land including cropland and pasture contribute to phosphorus loading to water bodies. These lands receive nutrients either via fertilizer application, biosolids application, or animal waste deposition. Maintaining a suitable cover over cropland and pasture minimizes phosphorus loads exiting such lands via soil erosion.

6.2.2 Developed Land

Runoff and sediment leaving developed areas contain phosphorus from lawn and green space fertilization (golf courses, playgrounds, parks), failing septic systems, straight pipes, and pets depositing on parks and backyards. The developed areas in the watershed include both pervious and impervious segments. Sediment and phosphorus loadings from impervious land segments are modeled through an accumulation rate set in the model. Loads from such areas usually enter water bodies without being filtered through soil or vegetated cover.

6.2.3 Forest/Wetlands/Water

Sediment and phosphorus contribution from forested lands are usually non-significant. This is due to the fact that erosion from forested lands, in general, is minimized by a considerable land cover that protects the soil from the energy of rainfall and runoff. Phosphorus from forest lands may originate from feces of wildlife and from atmospheric deposition. Waterfowl contribute to phosphorus loadings in wetlands and directly on water surfaces.

6.2.4 Groundwater Seepage

This source includes organic and/or inorganic phosphorus entering groundwater primarily from agricultural operations and septic systems. The contribution of groundwater can be considerable depending on the type of soil.

6.3 Obtaining Loads from the Reference Watershed

The Feeder Ditch watershed was used as a reference for modeling phosphorus in the target watersheds, Pocaty River and Ashville Bridge Creek. It was selected because, as with the target watersheds, it is relatively undeveloped, phosphorus originates from natural background sources, wetlands are extensive, and the topography is low. The reference watershed is also in the same ecoregion meaning it has similar weather, hydrology, and physiography. Finally, the Feeder Ditch was selected as a reference because it was the best available match in the region.

Because the phosphorus load of a watershed depends in part on its extent, the source land area in the Feeder Ditch watershed was adjusted by a factor to make it equal that of each target watershed. The phosphorus load estimated from the area-adjusted Feeder Ditch watershed was then applied to the target watershed as its allowable load. The loads from the individual land uses for the target and reference watersheds were not, and are not expected to be, the same because the areas of the individual land uses are different. Instead, a comparison of load differences of individual land uses is a tool for understanding why the existing phosphorous load in the target watershed is much higher that the reference watershed.

Page intentionally blank

7. PHOSPHORUS MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Computer modeling is used in this study as a tool for simulating the sediment loads to the Pocaty River and Ashville Bridge Creek from various activities within the watershed. The model chosen to simulate phosphorus loads was the *Visual Basic*™ version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001).

GWLF is a continuous simulation, spatially lumped model that operates on a daily time step for water balance calculations and monthly calculations for sediment and nutrients from daily water balance. In addition to runoff and sediment, the model simulates dissolved and attached nitrogen and phosphorus loads delivered to streams from watersheds with both point and nonpoint sources of pollution. The model considers flow input from both surface and groundwater. Land use classes are used as the basic unit for representing variable source areas. The calculation of nutrient loads from septic systems, and the inclusion of sediment and nutrient loads from point sources are also supported.

The model uses daily precipitation record to simulate runoff based on the Soil Conservation Service's Curve Number method (SCS, 1986). Erosion is calculated from a modification of the Universal Soil Loss Equation (USLE) (Schwab et al., 1981; Wischmeier and Smith, 1978). The portion of estimated erosion that reaches water bodies is calculated based on a delivery ratio which is calculated as a function of watershed area.

Virginia does not currently have a standard for phosphorus and therefore, a reference watershed approach was adopted to determine the endpoint. In a reference watershed approach, a reference stream with little or no anthropogenic impacts is used to determine an acceptable phosphorus load in the study areas. The Feeder Ditch to Dismal Swamp watershed was used as the reference watershed for the current study. Numeric endpoints were based on unit-area loading rates calculated for the reference watershed. The phosphorus TMDL was then developed for the impaired watersheds based on these endpoints and the results from load allocation scenarios. Details about the modeling procedures used are found in **Appendix D**.

.

8. PHOSPHORUS ALLOCATION

Total Maximum Daily Loads consist of waste load allocations (WLAs, permitted point sources) and load allocations (LAs, non-permitted sources), including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for uncertainties in the process. The definition is typically denoted by the expression:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS}$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For phosphorus, the TMDL is expressed in terms of annual load in kilograms per year (kg/yr).

This section describes the development of TMDLs for phosphorus for the Pocaty River and Ashville Bridge Creek using a reference watershed approach. The models were run over the period of 2001 to 2003 for modeling phosphorus allocations. The target phosphorus TMDL load for the impaired watersheds is the average annual load in kilograms per year (kg/yr) from the area-adjusted Feeder Ditch watershed under existing conditions minus a Margin of Safety (MOS).

8.1 Margin of Safety

In order to account for uncertainty in modeled output, an MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. For example, the typical method of assessing water quality through monitoring involves the collection and analysis of grab samples. The results of water quality analyses on grab samples collected from the stream may or may not reflect the "average" condition in the stream at the time of sampling. Calibration to observed data derived from grab samples introduces modeling uncertainty.

An MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The MOS for the phosphorus TMDL was explicitly expressed as 10% of the area-adjusted reference watershed load.

8.2 Future Growth Considerations

A future growth component was added to the WLA to account for any additional permits that may be issued in the future. A phosphorus load value for future growth was determined as 3% of the total TMDL. This was incorporated into the WLA for use as current discharges expand and for future permits that may discharge phosphorus.

The groundwater load is depicted as a single source in the model and in the TMDL reduction scenarios. However, it is the cumulative result of hydrologic and water quality impacts that result from activities on the landscape. BMPs, such as cover crops, nutrient management, and tree planting will serve to reduce this load.

8.3 Pocaty River Phosphorus TMDL

The target TMDL load for Pocaty River is the average annual load in kilograms per year (kg/yr) from the area-adjusted Feeder Ditch watershed under existing conditions. Under existing conditions, the load for Pocaty River was determined to be 2,400 kg/yr. Two different scenarios were run (**Table 8.1**). Phosphorus loads from straight pipes and failing septic systems were reduced 100% in all scenarios due to health implications of such sources. Scenario 1 shows similar reductions to sediment loads from agricultural and developed land uses in addition to reductions to failing septic systems and straight pipes loads. Scenario 2 shows reductions to loads from agricultural lands as well as the failing septic systems and straight pipes. Both scenarios meet the TMDL goal at a total phosphorus load reduction of approximately 57%. Scenario 1 was chosen to use for the final TMDL because it has reasonable reductions to loads from both agricultural and developed land uses.

Table 8.1 Final TMDL allocation scenario for the impaired Pocaty River watershed.

Total Phosphorus Source	Pocaty River Load (kg/yr)	Feeder Ditch load (kg/yr)	Scenario 1 Reductions[1]	Scenario1 Allocated Loads (kg/yr)	Scenario 2 Reductions	Scenario2 Allocated Loads
Pervious Area:						
Barren	6.8	46.65	63.96%	2.45		6.8
Conventional Tillage	1768.04	617.37	63.96%	637.2	66.0%	601.13
Conservation Tillage	1059.99	353.58	63.96%	382.02	66.0%	360.4
Forest	4.09	21.09		4.09		4.09
Disturbed Forest	8	15.09		8		8
Open Space	35.98	--		35.98		35.98
Hay	55.35	1.65	63.96%	19.95	66.0%	18.82
Unimproved Pasture	206.57	247.4	63.96%	74.45	66.0%	70.23
Cattle Grazed Pasture	110.05	4.96	63.96%	39.66	66.0%	37.42
Water	97.90	160.7		97.9		97.9
Wetland	106.19	188.56		106.19		106.19
Commercial	0.01	0.01		0.01		0.01
Residential	1.88	--	63.96%	0.68	66.0%	0.64
Developed	--	2.13				
Impervious Area:				0		
Commercial	--	0.51				
Residential	--	--				
Developed	--	18.58				
Open Space	--					
Groundwater	1,725.90	322.5	63.96%	622.01	66.0%	586.81
Septic Systems	107.36	260.74	100.00%	0	100.0%	0
Direct Sources:						
Straight Pipes	11.62	138.52	100.00%	0	100.0%	0
Permitted Sources:						
VAG403065	3.45	--		3.45		3.45
MS4-Virginia Beach and VDOT MS4	2.99	--	63.96%	1.08		2.99
MS4-Chesapeake and VDOT MS4	146.69	--	63.96%	52.86		146.69
Margin of Safety				240		240
Future Growth	72	--		72		72
Watershed Total	*5,530.86*	*2,400.04*		2,399.98		2,399.55

[1] .. Final TMDL scenario.

The final overall phosphorus load reduction required for Pocaty River is 56.61% (**Table 8.2**).

Table 8.2 Required phosphorus reductions for Pocaty River watershed.

Load Summary	Pocaty River (kg/yr)	Reductions Required (kg/yr)	Reductions Required (% of existing load)
Existing Phosphorus Load	5,530.86		
Target Modeling Load	2,400.04		
Final Allocated Load (WLA+LA)	2,399.98	3,130.18	56.61%

The phosphorus TMDL for Pocaty River watershed includes three components – WLA, LA, and the 10% MOS. The WLA was calculated as the sum of all permitted point source discharges. The LA was calculated as the target TMDL load minus the WLA load minus the MOS (**Table 8.3**).

Table 8.3 Average annual phosphorus TMDL for Pocaty River watershed.

Impairment	WLA (kg/yr)	LA (kg/yr)	MOS (kg/yr)	TMDL (kg/yr)
Pocaty River	**129.39**	**2,030.59**	**240.00**	**2,399.98**
VADEQ VPDES permits:				
VAG403065	3.45			
MS4-Virginia Beach and VDOT MS4	1.08			
MS4-Chesapeake and VDOT MS4	52.86			
Future Growth	*72.00*			

WLA is expressed as the summation of all individual permit loads and future growth.

Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Starting in 2007, the USEPA has mandated that TMDL studies include a maximum "daily" load (MDL) as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach found in the 2007 document titled "Options for Expressing Daily Loads in TMDLs" (USEPA, 2007). The procedure involved calculating the MDL from the long-term average annual TMDL load in addition to a coefficient of variation (CV) estimated from the annual load for ten years. The annual phosphorus load ranged from 2,500 kg to 9,000 kg with a CV of 0.44. A multiplier was used to estimate the MDL from the long-term average based on the USEPA guidance. The multiplier estimated was 2.58. In this case, the long-term average was the annual TMDL divided by 365.25 days multiplied by 2.58 resulting in a MDL of approximately 17 kg/day. The daily WLA was estimated as the annual WLA divided by 365. The daily MOS was estimated as 10% of the MDL. Finally, the daily LA was estimated as the MDL minus the daily MOS minus the daily WLA. These results are shown in **Table 8.4**.

Table 8.4 Daily phosphorus loads (kg/day) for Pocaty River.

Impairment	WLA* (kg/day)	LA (kg/day)	MOS (kg/day)	TMDL (kg/day)
Pocaty River	0.665	14.576	1.694	16.935
VADEQ VPDES permits:				
VAG403065	0.009			
MS4-Virginia Beach and VDOT MS4	0.003			
MS4-Chesapeake and VDOT MS4	0.145			
Future Growth	*0.508*			

* WLA is expressed as the summation of all individual permit loads.

Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

8.4 Ashville Bridge Creek Phosphorus TMDL

The target TMDL load for Ashville Bridge Creek is the average annual load in kilograms per year (kg/yr) from the area-adjusted Feeder Ditch watershed under existing conditions. Under existing conditions, the load for Ashville Bridge Creek was determined to be 516 kg/yr. Two different scenarios were run (**Table 8.5**). Phosphorus loads from straight pipes and failing septic systems were reduced 100% in all scenarios due to health implications of such sources. Scenario 1 shows similar reductions to sediment loads from agricultural and developed land uses in addition to reductions to failing septic systems and straight pipes loads. Scenario 2 shows reductions to loads from agricultural lands as well as the failing septic systems and straight pipes. Both scenarios meet the TMDL goal at a total phosphorus load reduction of 35%. Scenario 1 was chosen to use for the final TMDL because it has reasonable reductions to loads from both agricultural and developed land uses.

Table 8.5 Final TMDL allocation scenario for the impaired Ashville Bridge Creek watershed.

Total Phosphorus Source	Ashville Bridge Creek Load (kg/yr)	Feeder Ditch load (kg/yr)	Scenario 1 Reductions[1]	Scenario1 Allocated Loads (kg/yr)	Scenario 2 Reductions	Scenario2 Allocated Loads (kg/yr)
Pervious Area:						
Barren	0	8.26		0		0
Conventional Tillage	354.96	98.4	42.89%	202.72	44.9%	195.72
Conservation Tillage	63.14	53.24	42.89%	36.06	44.9%	34.82
Forest	0.7	2.96		0.7		0.7
Disturbed Forest	1.08	2.64		1.08		1.08
Open Space	4.74	--		4.74		4.74
Hay	1.72	0.21	42.89%	0.98	44.9%	0.95
Unimproved Pasture	55.16	35.63	42.89%	31.5	44.9%	30.42
Cattle Grazed Pasture	1.99	0.64	42.89%	1.14	44.9%	1.1
Water	12.82	19.63		12.82		12.82
Wetland	16.76	24.23		16.76		16.76
Commercial	0	0		0		0
Residential	1.62	--		1.62	44.9%	0.89
Developed	--	0.35				
Impervious Area:						
Commercial	--	0.06				
Residential	--	--				
Developed	--	2.27				
Open Space						
Groundwater	208.89	97.78	42.89%	119.3	44.9%	115.18
Septic Systems	11.89	30.68	100.00%	0	100.0%	0
Direct Sources:						0
Straight Pipes	3.87	138.52	100.00%	0	100.0%	0
Permitted Sources:						
MS4-Virginia Beach and VDOT MS4	33.26	--	42.89%	18.99		33.26
Margin of Safety				51.55		51.55
Future Growth	15.47	--		15.47		15.47
Watershed Total	*788.07*	*515.50*		515.43		515.46

[1] .. Final TMDL scenario.

The final overall phosphorus load reduction required for Ashville Bridge Creek is 34.59% (**Table 8.6**).

Table 8.6 Required phosphorus reductions for Ashville Bridge Creek watershed.

Load Summary	Ashville Bridge Creek (kg/yr)	Reductions Required (kg/yr)	(% of existing load)
Existing Phosphorus Load	788.07		
Target Modeling Load	515.50		
Final Allocated Load (WLA+LA)	515.43	272.64	34.59%

The phosphorus TMDL for Ashville Bridge Creek watershed includes three components – WLA, LA, and the 10% MOS. The WLA was calculated as the sum of all permitted point source discharges. The LA was calculated as the target TMDL load minus the WLA load minus the MOS (**Table 8.7**).

Table 8.7 Average annual phosphorus TMDL for Ashville Bridge Creek watershed.

Impairment	WLA (kg/yr)	LA (kg/yr)	MOS (kg/yr)	TMDL (kg/yr)
Ashville Bridge Creek	34.46	429.42	51.55	515.43
MS4-Virginia Beach and VDOT MS4	18.99			
Future Growth	*15.47*			

WLA is expressed as the summation of all individual permit loads.

Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Starting in 2007, the USEPA has mandated that TMDL studies include a maximum "daily" load (MDL) as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach found in the 2007 document titled Options for Expressing Daily Loads in TMDLs (USEPA, 2007). The procedure involved calculating the MDL from the long-term average annual TMDL load in addition to a coefficient of variation (CV) estimated from the annual load for ten years. The annual phosphorus load ranged from 380 kg to 1,280 kg with a coefficient of variation (CV) of 0.43. A multiplier was used to estimate the MDL from the long-term average based on the USEPA guidance. The multiplier estimated for the Ashville Bridge Creek was 2.44. In this case, the long-term average was the annual TMDL divided by 365.25 days multiplied by 2.44 resulting in a MDL of 3.45 kg/day. The daily WLA was estimated as the annual WLA divided by 365.25. The daily MOS was estimated as 10% of the MDL. Finally, the daily LA was estimated as the MDL minus the daily MOS minus the daily WLA. These results are shown in **Table 8.8**.

Table 8.8 Daily phosphorus loads (kg/day) for Ashville Bridge Creek.

Impairment	WLA* (kg/day)	LA (kg/day)	MOS (kg/day)	TMDL (kg/day)
Ashville Bridge Creek	0.155	2.946	0.345	3.446
MS4- Virginia Beach and VDOT MS4	0.052			
Future Growth	*0.103*			

* WLA is expressed as the summation of all individual permit loads.

Each of the municipality MS4 loads has been aggregated with a portion of the adjacent VDOT MS4 load, due to the continuity of the system. For MS4/VSMP permits, the permittee may address the TMDL WLAs for stormwater through the iterative implementation of programmatic BMPs.

Page intentionally blank

9. pH TMDL DEVELOPMENT

9.1 Ashville Bridge Creek

Ashville Bridge Creek is an estuary within the City of Virginia Beach. (**Figure 9.1**). The impaired section lies between Hell Point Creek and the Muddy Creek confluence. Ashville Bridge Creek lies within the Middle Atlantic Coastal Plain ecoregion and land use is primarily crop, wetlands and forest.

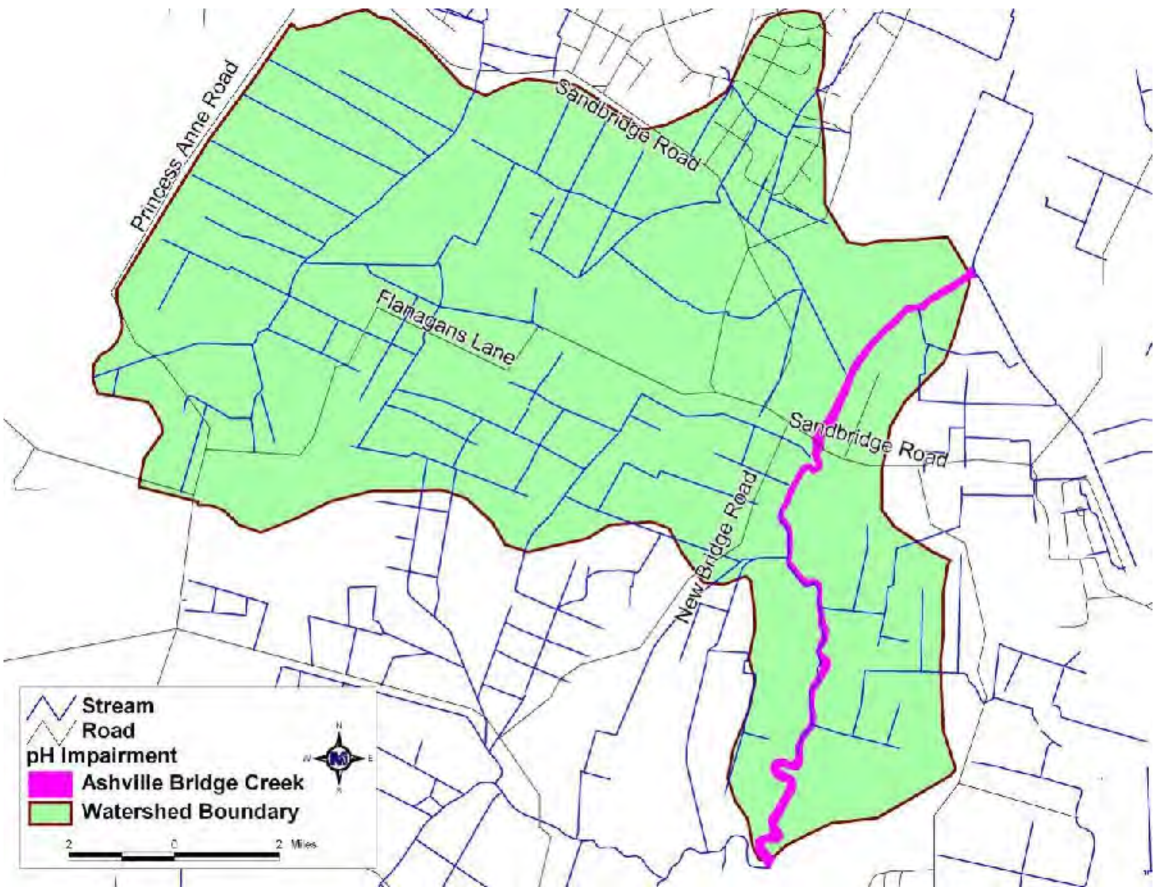

Figure 9.1 Location of the Ashville Bridge Creek watershed low pH project in Virginia Beach.

9.2 Water Quality Data

VADEQ has collected data on Ashville Bridge Creek at station 5BASH002.20 between May 2003 and July 2006 and two pH measurements out of 20 were below the minimum standard of 6.0 standard units (**Figure 9.2**).

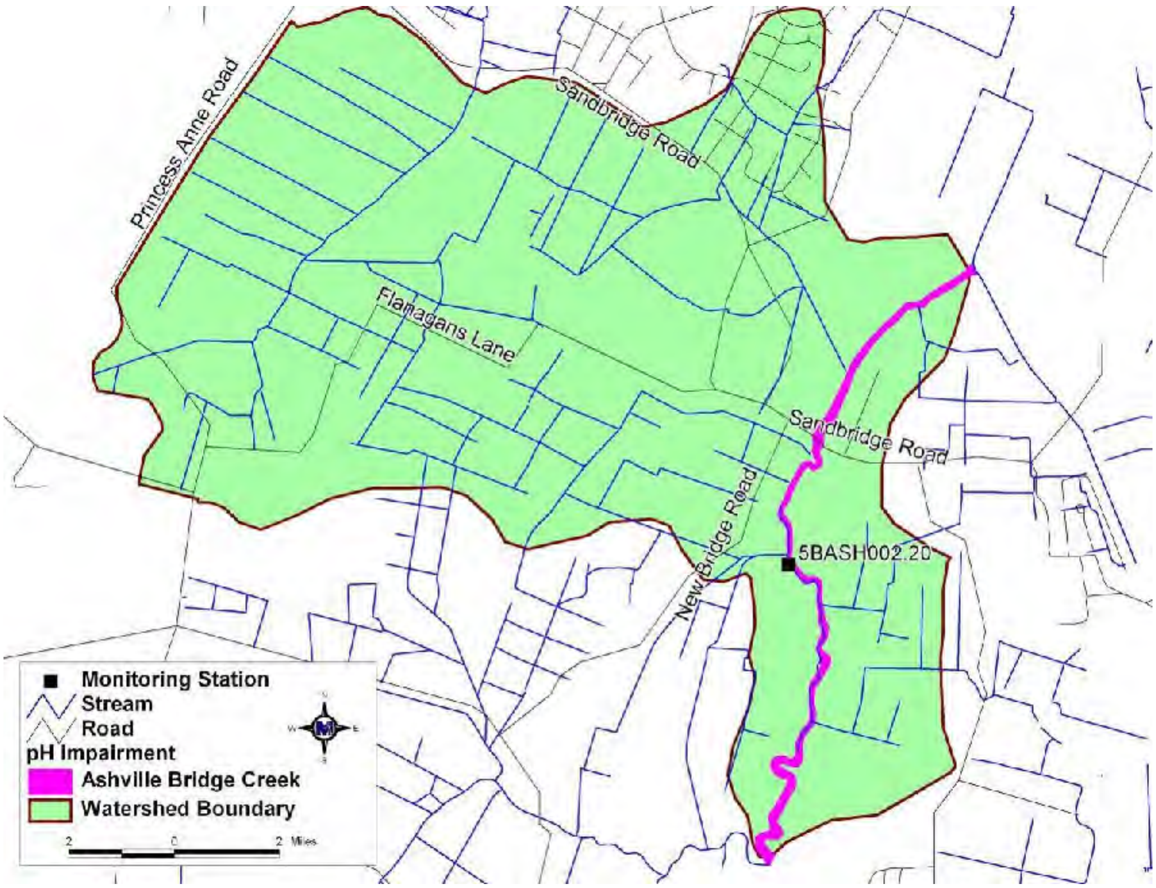

Figure 9.2 Location of the monitoring station on Ashville Bridge Creek.

9.3 Source Assessment

Ashville Bridge Creek is located entirely within the City of Virginia Beach and there exist the City of Virginia Beach MS4 and VDOT MS4 permitted discharges in the Ashville Bridge Creek watershed.

9.3.1 Ashville Bridge Creek Low pH Discussion

Ashville Bridge Creek has natural tendency toward low pH measurements (MapTech, 2013). In addition anthropogenic sources also play a role in low pH measurements. Excessive nutrients such as total phosphorus, organic matter and acid deposition are anthropogenic sources that play a role in low pH measurements.

In 1977 the National Atmospheric Deposition Program (NADP) began measuring atmospheric deposition and studying its effects on the environment. The network grew rapidly in the early 1980s. Much of this expansion was funded by the National Acid Precipitation Assessment Program (NAPAP), established in 1981 to improve understanding of the causes and effects of acidic precipitation. Atmospheric deposition sampling by the National Atmospheric Deposition Program in 2006 in the Virginia Beach area finds pH values as low as 4.5 std units (http://nadp.sws.uiuc.edu/lib/data/2006as.pdf).

Acid rain is precipitation in the form of rain, snow, hail, dew, or fog that transports sulfur and nitrogen compounds from the high atmosphere to the ground. Sulfur dioxide (SO_2) and nitrogen oxides (NO, NO_2) are bi-products from burning fuels in electric utilities and from other industrial and natural sources. These chemicals react with water, oxygen, carbon dioxide, and sunlight in the atmosphere to form sulfuric and nitric acids. The acids reach the ground and change the chemistry within the environment.

Determining the pH of “normal” rain is complex. When distilled water is exposed to air, an interaction with carbon dioxide increases acidity through the formation of carbonic acid, H_2CO_3, and the pH level falls. Many scientists agree that the normal pH of rain is a slightly acidic 5.6 because of perpetual chemical interactions in the air. Seasons, climate, and a host of other factors can also influence the acidity of rain.

Rain and snow are not the only processes that deposit sulfur and nitrogen acids from the atmosphere to the ground. These compounds are also present in gases and dry particles, which are more difficult to measure. The occurrence of “dry deposition” of acids varies in different areas, depending on distance from the emission source and climatic conditions.

Acid rain is linked to both natural and man-made sources. Nitrogen oxides are formed through the extreme heating of air when a thunderstorm produces lightning. Also, sulfurous gases are discharged from erupted volcanoes and rotting vegetation.

Man-made sources of acid rain include the burning of any fuel that contains sulfur and nitrogen compounds, including public utilities, industrial broilers, motor vehicles, and chemical plants. Electric power generation accounted for 69 percent of total sulfur dioxide emissions in the U.S. in 2007 and 20 percent of nitrogen oxides, according to the U.S. Environmental Protection Agency (USEPA).

Many industrial sources of sulfur dioxide are located in the eastern U.S., particularly in the Midwest and the Ohio Valley where coal combustion and power generation frequently occur. Typically, the highest nitrogen oxide emissions are found in states with large urban areas, a heavy population density, and significant automobile traffic.

Acid rain is not limited to the region where sources are located. Prevailing winds can blow chemicals in the atmosphere for hundreds or even thousands of miles before being deposited, regardless of state and country boundaries. For instance, compounds from industry in China can potentially be deposited in the U.S. Midwest. For this reason, acid rain is considered a global problem.

Acid rain has been linked to detrimental effects in the environment and in human health. When lakes and streams become more acidic than normal, they cannot continue to support the same types of fish and aquatic life as in the past. Fish communities dwindle due to high mortality, a reduced growth rate, skeletal deformities, and failed reproduction. Game fish, such as trout, are particularly sensitive to acidic water conditions. Only a few fish species can survive at a pH of below 5. A decrease in fish populations is often the first sign of an acidification problem.

Acidic fog can be more hazardous to human health than acid rain as small droplets can be inhaled. These atmospheric acids can cause respiratory problems in humans such as throat, nose, and eye irritation, headache, and asthma. Acid fog is particularly dangerous for the elderly, those who are ill, and people who have chronic respiratory conditions. (http://nadp.sws.uiuc.edu/educ/acidrain.aspx).

9.3.2 Soil Buffering Capacity

Soils within the Ashville Bridge Creek watershed are comprised soil series with a "High" corrosion to concrete, indicating that the soils in the watershed are highly acidic.

9.4 TMDL Development

The TMDL load is expressed as a load of pollutant per day and/or year. The TMDL for pH is not a simple translation from the pH of the subject waters because pH is a dimensionless number. In addition, despite conventional expectation, it is only proportional to the concentration of Hydrogen ions in a waterbody. The following is the accurate conversion from pH to concentration.

$$[H^+] = \{H^+\} / g = 10^{-pH} / g$$

where g is the H^+ activity coefficient, and $\{H^+\}$is Hydrogen ion activity.

The pH probes used to monitor stream acid:base condition measure hydrogen ion activity ($\{H^+\}$). In distilled water the activity coefficient is about 1.0. As a result, the Hydrogen ion concentration essentially equals the ion activity. But, in acid-impaired streams where the ionic strength of H^+ is high, the activity coefficient is less than 1.0. Thus, for accurate development of a pH TMDL, the challenge is to determine the actual H^+ load in the waterbody through an estimate of the H^+ activity coefficient (g).

9.4.1 Calculating H^+ Concentration

In solute-laden waters using 10^{-pH} to estimate Hydrogen ion concentration will under-estimate the H^+ concentration. The ionic strength of these waters is high so the activity coefficient g will be less than 1.0 and the effective H^+ concentration will be greater than that predicted by the standard 10^{-pH}.

The pH of a waterbody equals the log of H^+ activity. In Ashville Bridge Creek the lowest pH measured by the VADEQ was 5.7 standard units.

$\{H^+\} \quad = \quad 10^{-pH} \quad = \quad 10^{-5.7} \quad = \quad 0.0000020$ moles/L ion activity

This measure is converted to concentration by dividing it by the activity coefficient g, which depends on the ionic strength u, of the water sample. The ionic strength u is estimated from the total dissolved solids (TDS in mg/L) through the following relationship. The 90th percentile TDS concentration in Ashville Bridge Creek is 546 mg/L.

$u \quad = \quad TDS * 2.5*10^{-5} \quad = \quad 546 * 2.5*10^{-5} \quad = \quad 0.01365$

Then, having calculated u, **Figure 9.3** is used to find the activity coefficient g. In our example where u is 0.01365, g is 0.90.

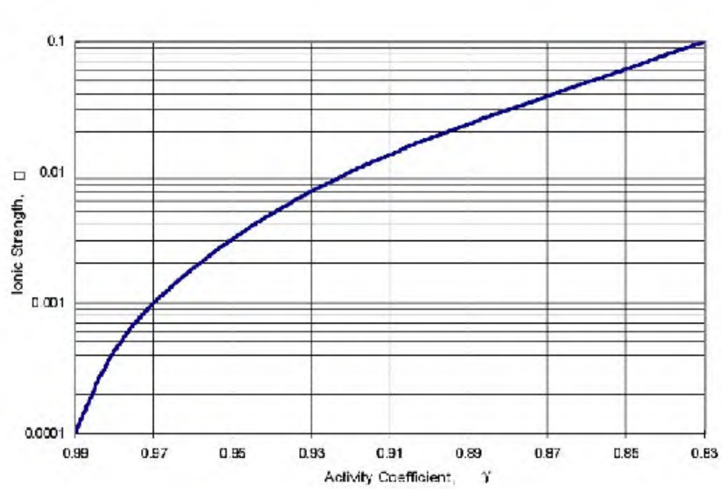

Figure 9.3 Activity coefficients of H^+ as a function of ionic strength (KDEP 2006)

For Ashville Bridge Creek where g = 0.90, the actual Hydrogen ion concentration is the following.

$[H^+] = \{H^+\} / g = 10^{-5.7} / 0.9 = 0.00000200 / 0.9 = 0.0000022$ moles/L

where g is the activity coefficient and $\{H^+\}$ is Hydrogen ion activity.

Because the atomic weight of Hydrogen is 1 g/mole, a concentration of H^+ in moles/L is also the concentration in grams/L. The result is converted to g/cu.ft. to match the typical units of flow as follows.

$[H^+]$ = (0.0000022 g/L)*1 L/0.035314667 cu.ft. = 0.0000628 g/cu.ft.

This is the Hydrogen ion concentration at the measured pH 5.7.

9.4.2 Margin of Safety

A margin of safety (MOS) is achieved by employing an activity coefficient (g) of 1.0 in the TMDL load calculation based on flow (**Figure 9.4**). The magnitude of the MOS is determined by comparing the load obtained using g = 1.0 and the calculated activity coefficient. For our example, the calculated activity coefficient is 0.9. Then for the example, the margin of safety is (1.0 – 0.9)*100% = 10%.

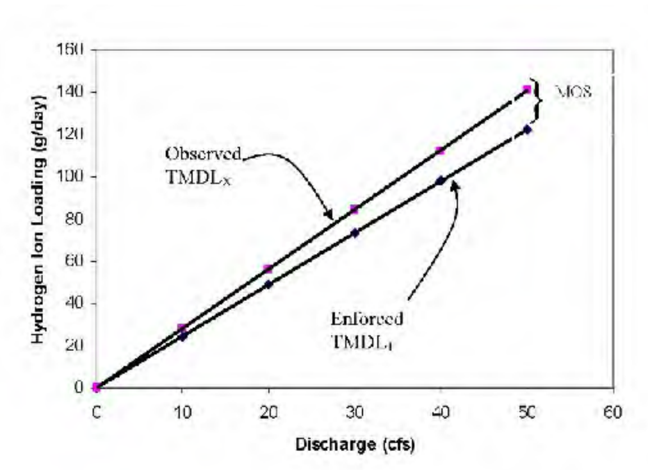

Figure 9.4 Relation between discharge and maximum ion load for a pH of 6.0 (KDEP 2006)

9.4.3 Calculating H^+ Load

The Hydrogen ion concentration in the impaired waterbody was calculated in Section 9.4.1 as the weight of H^+ in grams/cu.ft. The daily load of Hydrogen ions in the impaired waterbody depends on the Hydrogen ion concentration and the volume of water being discharged (Q). Based on the HSPF model used in this study for the bacteria TMDL, the average flow from Ashville Bridge Creek is 23.23 cfs. Multiplying the H^+ concentration by the flow rate in cfs produces the daily H^+ load in grams/day as follows.

H^+ load = $[H^+]$*Q*a

where, load is in (g/day), concentration is in g/cu.ft., flow is in cfs, and "a" is the unit conversion from seconds to days.

In our example watershed, the Hydrogen ion load at a pH of 5.7 is as follows.

H^+ load = (0. 00000628 g/cu.ft.) * 23.23 cfs * 86,400 s/day = 12.6 g/day

The maximum allowable load is defined by a pH 6.0. Then, the daily TMDL is the H+ load calculated for the average daily flow and a minimum pH of 6. Also, for an average day the difference between the average observed and the average TMDL-allowed at that flow is the TMDL reduction.

In our example watershed, to provide a margin of safety at the pH threshold of 6.0, an activity coefficient of 1.0 is used. Then, the allowable load at pH = 6.0, as used in the TMDL, is as follows.

$$\text{Allowable } H^+ \text{ Load} = [(10^{-6} \text{ g/L} / 0.035314667 \text{ cf/L}) / 1.0] * 23.23 \text{ cfs} * 86{,}400 \text{ s/day}$$

$$= 5.683 \text{ g/day}$$

The TMDL load at pH = 6.0 with an activity of 0.9 would be 6.315 g/day. Thus, by using an activity of 1.0 the MOS is 1 – (5.683/6.315) or 10%.

The TMDL reduction needed in the impaired watershed is the difference between the load at the observed pH and the load allowed at pH 6.0. The reduction needed is as follows.

$$\text{TMDL load reduction} = (H^+ \text{ load at observed pH}) - (H^+ \text{ load at pH=6.0 with g = 1.0})$$

$$= 12.6 \text{ g/day} - 5.683 \text{ g/day} = 6.917 \text{ g/day} \quad (54.8\%)$$

9.5 Permitting

The City of Virginia Beach MS4 aggregated with the VDOT MS4 discharges in the Ashville Bridge Creek watershed permitted for pH control. Because of the watershed-outlet focus of the TMDL, all streams in the impaired watershed are considered impaired. New permits for discharges to streams in the watershed could be allowed with end-of-pipe pH limits of 6.0 – 9.0 SU. Because the streams are pH-impaired, new discharges cannot cause or contribute to the impairment. With a pH permit limit between 6.0 and 9.0 std units, any new discharge(s) will not cause or contribute to the low pH impairment. Therefore, new permits will not be assigned a H^+ load as part of a WLA.

9.6 TMDL

Table 9.1 shows the average annual TMDL, which gives the average amount of H^+ ions that can be present in the stream in a given year, and still meet the minimum pH water quality standard.

Table 9.1 Final average annual in-stream H^+ load (g/year) modeled in Ashville Bridge Creek.

Impairment	WLA (g/yr)	LA (g/yr)	MOS	TMDL (g/yr)
Ashville Bridge Creek	0.0	2,075	230	2,305
MS4- Virginia Beach and VDOT MS4[1]	--			
Future Growth[2]	--			

[1] .. A pH of level between 6.0 and 9.9 standard units is assumed.
[2] .. With a pH permit limit between 6.0 and 9.0 standard units, any new discharge(s) will not cause or contribute to the low pH impairment.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The daily average in-stream load for the Ashville Bridge Creek pH impairment is shown in **Table 9.2**.

Table 9.2 Final average daily in-stream H^+ load (g/day) modeled in the Ashville Bridge Creek.

Impairment	WLA (g/day)	LA (g/day)	MOS	TMDL (g/day)
Ashville Bridge Creek	0.0	5.685	0.63	6.315
MS4- Virginia Beach and VDOT MS4[1]	--			
Future Growth[2]	--			

[1] .. A pH of level between 6.0 and 9.9 standard units is assumed.
[2] .. With a pH permit limit between 6.0 and 9.0 standard units, any new discharge(s) will not cause or contribute to the low pH impairment.

Page intentionally blank

10. IMPLEMENTATION

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. EPA requires that there is reasonable assurance that TMDLs can be implemented. TMDLs represent an attempt to quantify the pollutant load that might be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Commonwealth intends to use existing programs in order to attain water quality goals.

The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

10.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on the VADEQ web site under http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ppp.pdf.

10.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

10.3 Implementation of Waste Load Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

10.3.1 Stormwater

Prior to July 1, 2013, VADEQ and VADCR coordinated separate state permitting programs that regulated the management of pollutants carried by stormwater runoff. Since July 1, VADEQ regulates both stormwater discharges associated with industrial activities through its VPDES program, and stormwater discharges from construction sites and from municipal separate storm sewer systems (MS4s) through its VSMP program. As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented. More information regarding these programs can be found at http://www.deq.virginia.gov/Programs/Water/StormwaterManagement.aspx.

10.3.2 TMDL Modifications for New or Expanding Discharges

Permits issued for facilities with waste load allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these waste load allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at http://www.deq.virginia.gov/Portals/0/DEQ/Water/Guidance/052011.pdf.

10.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

10.4.1 Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19:7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments". EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003. It is available upon request from the VADEQ and VADCR TMDL project staff or at www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

10.4.2 Staged Implementation Scenarios

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. Among the most efficient bacterial BMPs for both urban and rural watersheds are stream side fencing for cattle farms, pet waste clean-up programs, and government or grant programs available to homeowners with failing septic systems and installation of treatment systems for homeowners currently using straight pipes.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis (UAA) may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and by implementing cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in Section 6.6.

10.4.3 Link to Ongoing Restoration Efforts

Implementation of these TMDLs will contribute to on-going water quality improvement efforts aimed at restoring water quality in Ashville Bridge Creek watershed. Implementation of these TMDLs will also contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay.

10.4.4 Implementation Funding Sources

The implementation of pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding source for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Guidance on WQIF applications can be obtained by contacting John Kennedy, VADEQ Chesapeake Bay Program, at jmkennedy@deq.virginia.gov.

10.5 Follow-Up Monitoring

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired streams in accordance with its ambient monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with *DEQ Guidance Memo No. 04-2005* (http://www.deq.virginia.gov/Portals/0/DEQ/Water/Guidance/042005b.pdf), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. The details of the follow-up ambient monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office.

VADEQ staff, in cooperation with the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plans. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or to monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on VADEQ's citizen monitoring and QA/QC guidelines is available at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring.aspx.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years.

10.6 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses are expected to be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. UAAs may be developed by any stakeholder at any time before, during, or after the TMDL process. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment. Additional information can be obtained at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityStandards/DesignatedUses.aspx.

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation is that all controllable sources would be reduced to the maximum extent possible using the implementation approaches described above. VADEQ will continue to monitor water quality in the stream during and subsequent to the implementation of these measures to determine if the water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA may then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed".

Page intentionally blank

11. PUBLIC PARTICIPATION

Public participation during TMDL development for the Back Bay, North Landing River and Pocaty River study area was encouraged. A public meeting was held on February 27, 2013 to introduce the public to the project and present initial estimates of bacteria sources within the study area. The meeting was held at the Creek Ruritan Barn – Virginia Beach Farm Bureau Office in Virginia Beach, Virginia. A Technical Advisory Committee meeting was held on September 30, 2012. A final public meeting was held on October 22, 2013 to present the allocation results and final TMDL tables. The final public meeting was also used as a kickoff meeting for the implementation plan phase. Information about the TMDL meetings is presented in **Table 11.1**.

Table 11.1 Public participation during TMDL development for the Back Bay, North Landing River and Pocaty River watersheds.

Date	Location	Attendance[1]	Type
10/03/2011	Virginia Beach Farm Bureau Office Virginia Beach, VA	14	Public/Technical Advisory Committee
2/27/2013	Virginia Beach Farm Bureau Office Virginia Beach, VA	14	1st Public
9/30/2013	VADEQ Tidewater Regional Office, Virginia Beach, VA	9	Technical Advisory Committee
10/22/2013	Virginia Beach Farm Bureau Office Virginia Beach, VA	11	2nd Public

[1] ¨ The number of attendants is estimated from signup sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

Public participation during the implementation plan development process will include the formation of stakeholders' committees, with committee and public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. Stakeholder committees will have the express purpose of formulating the TMDL Implementation Plan. The committees will consist of, but not be limited to, representatives from VADEQ and local governments. These committees will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

REFERENCES

American Veterinary Medical Association – Center for Information Management. 1997 U.S. Pet Ownership and Demographics Sourcebook.

American Veterinary Medical Association – Center for Information Management. 1997 U.S. Pet Ownership and Demographics Sourcebook.

Armour, C.L., D.A. Duff and W. Elmore. 1991. AFS Position Statement. Fisheries, Jan/Feb 1991, p. 7-11.

ASAE Standards, 45th Edition. 1998. D384.1 DEC93. Manure Production and Characteristics. St. Joseph, Mich.: ASAE.

ASAE Standards, 45th Edition. 1998. D384.1 DEC93. Manure Production and Characteristics. St. Joseph, Mich.: ASAE.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, Benthic macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water, Washington, D.C.

Bidrowski, T. 2003, Virginia Department of Game and Inland Fisheries. Personal telecommunication, 01/29/03.

Bidrowski, T. 2004. Virginia Department of Game and Inland Fisheries. Personal telecommunication. July 16, 2004 and August 9, 2004.

BSE. 2003. Benthic TMDL for Stroubles Creek in Montgomery County, Virginia. Department of Biological Systems Engineering, Virginia Tech.

Burton, J. and J. Gerritsen, 2003. A Stream Condition Index for Virginia Non-coastal Streams. Tetra Tech, Inc. Owings Mills, Maryland.

Clary, W.P. and B.F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region. USDA, Forest Service, Intermountain Research Station, General Technical Report INT-263, Ogden, UT.

Costanzo, G. 2003, Virginia Department of Game and Inland Fisheries. Personal telecommunication, 01/29/03.

Draper Aden Associates. 2009. County Of Henrico Springfield Sanitary Landfill Groundwater Monitoring Program – Corrective Action Site Evaluation – Permit No. 545.

England, C.B. 1970. Land Capability: A Hydrologic Response Unit in Agricultural Watersheds. Agricultural Research Service, USDA, ARS: 41-172.

Evans, Barry M., S. A. Sheeder, K. J. Corradini, and W. W. Brown. 2001. AVGWLF version 3.2 Users Guide. Environmental Resources Research Institute, Pennsylvania State University and Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation.

Farrar, R. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication.

Fies, M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. 08/11/04, 08/12/04, and 08/24/04.

Geldreich, E. E. 1978. Bacterial Populations and Indicator Concepts in Feces, Sewage, Stormwater, and Solid Wastes. In Indicators of Viruses in Water and Food, ed. G. Berg. Ann Arbor, Mich.: Ann Arbor Science Publishers, Inc.

Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. Water Resources Bulletin, 23(3), pp. 471-478.

Haith, D.A., R. Mandel, and R.S. Wu. 1992. GWLF. Generalized Watershed Loading Functions, version 2.0 User’s Manual. Department of Agricultural and Biological Engineering, Cornell University, Ithaca, New York.

Joyce Engineering. 2002. Nature and Extent Study. Springfield Road Sanitary Landfill – Permit No. 545.

Kaufman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian plant communities, and streamside management implications. A review. Journal of Range Management 37(3): 430-437.

Kaufmann, P. R., John M. Faustini, David P. Larsen, and Mostafa A. Shirazia. 2008. A roughness-corrected index of relative bed stability for regional stream surveys. Geomorphology. Volume 99, Issues 1-4, 1 July 2008, Pages 150-170.

Kaufmann, P. R., P. Levine, E. G. Robinson, C. Seeliger, and D. Peck. 1999. Quantifying physical habitat in wadeable streams. EPA/620/R-99/003, USEPA, Washington, D.C.

Kleene, J. Wesley. 1995, Watershed Nonpoint Source Management System: A Geographic Information System Approach, Ph.D. Dissertation, Virginia Polytechnic Institute and University.

Knox, W. M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. August 03, 2004, August 05, 2004, and August 25, 2004.

Li, E.A. 1975. A model to define hydrologic response units based on characteristics of the soil-vegetative complex within a drainage basin. M.S. Thesis, Department of Agricultural Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Lloyd, K. 2004. Virginia Department of Environmental Quality. Personal telecommunication. September 28, 2004.

MapTech. July 2013. Low Dissolved Oxygen (DO) & pH Assessment for Back Bay and North Landing River Tributaries. Submitted to VDEQ, Richmond, VA.

MapTech. July 2006. Natural Condition Assessment for Low Dissolved Oxygen Feeder Ditch to Dismal Swamp, Chesapeake, Virginia. Submitted to VDEQ, Richmond, VA.

MapTech. 2002. Modeling Cattle Stream Access. Submitted to: VADCR, in cooperation with Biological Systems Engineering Department, Virginia Tech.

MapTech. 1999. Unpublished source sampling data. Blackwater River TMDL Study.

Mayhorn, R. 2005. Buchanan County Bird Club. Personal Communication. 08/17/05.

McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus Based Sediment Quality Guidelines For Freshwater Ecosystems. Arch. *Environ. Contam. Toxicol.* 39: 20-31.

Norman, G. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. July 12, 2004.

Norman, G.W. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication.

Novotny, V., and G. Chesters. 1981. Handbook of Nonpoint Pollution. Van Nostrand Reinhold, New York, NY.

NRCS. 2012. Regional Hydraulic Geometry Curves. http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/

NRCS. 2012. SSURGO website. http://soils.usda.gov/survey/geography/ssurgo/

Raftovich, R. V. 2004. Atlantic Flyway Breeding Waterfowl Plot Survey: Breeding Pair and Population Size Estimates 2004. U.S. Fish and Wildlife Service. Division of Migratory Bird Management. July 28, 2004.Reneau, R.B., Jr. 2000. Department of Crop and Soil Environmental Sciences, Virginia Tech. Personal communication. January 7, 2000.

Rose, R.K., Cranford, J.A. 1987. Handbook of Virginia Mammals. Final Report, Project No. 567460. VA Dept. Game & Inland Fisheries, Richmond, VA: 121.

Schwab, G. O., R. K. Frevert, T. W. Edminster, and K. K. Barnes. 1981. Soil and Water Conservation Engineering. 3rd ed. New York: John Wiley & Sons.

SCS. 1986. Urban Hydrology for Small Watersheds, USDA Soil Conservation Service, Engineering Division, Technical Release 55.

SERCC. 2011. Southeast Regional Climate Center. http://www.sercc.com/

SERCC. 2012. Southeast Regional Climate Center.

USCB, 1990. *1990 Census*. United States Census Bureau. Washington D.C.

USCB, 2000. *2000 Census*. United States Census Bureau. Washington D.C.

USDI, Bureau of Land Management. 1998. Riparian area management: process for assessing proper functioning conditions. Technical Reference 1737-9, National Applied Science Center, Denver, CO.

USEPA, 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. December 2000. EPA 822-B-00-025.

USEPA, 2007. Options for Expressing Daily Loads in TMDLs.

USEPA, 2007. Options for Expressing Daily Loads in TMDLs.

VADCR and VADEQ. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans. http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/ImplementationPlans/ipguide.pdf.

VADCR and VADEQ. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans. http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

VADEQ. 2002. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2003b. Guidance Memo No. 03-2004. Managing Water Monitoring Programs While Under Reduced Resources. Memo from Larry G. Lawson to Regional Directors of the VADEQ. February 10, 2003. Accessible at: http://www.deq.virginia.gov/Portals/0/DEQ/Water/Guidance/042005b.pdf

VADEQ. 2004. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2006. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2008. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2003a. Guidance Memo No. 03-2012. HSPF Model Calibration and Verification for Bacteria TMDLs. Memo from Larry G. Lawson to Regional Directors. September 3, 2003.

VADEQ. 2010. Final 2010 305(B)/303(D) Water Quality Assessment Integrated Report. Chapter 2.4. http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityAssessments/2010305b303dIntegratedReport.aspx.

VADEQ. 2010. Final 2010 305(B)/303(D) Water Quality Assessment Integrated Report. Chapter 2.4. http://www.deq.virginia.gov/wqa/ir2010.htmlAmerican Veterinary Medical Association – Center for Information Management. 1997 U.S. Pet Ownership and Demographics Sourcebook.

VASS. 1999. Virginia Agricultural Statistics Bulletin 1997. Virginia Agricultural Statistics Service. Richmond, VA.

VASS. 2005. Virginia Agricultural Statistics Bulletin 2001. Virginia Agricultural Statistics Service. Richmond, VA.

VDGIF. 1999. www.dgif.state.va.us. Virginia Fish and Wildlife Information Service.

Weiskel. P. A., B. L. Howes, and G. R. Heufelder. 1996. Coliform contamination of a coastal embayment: sources and transport pathways. Environ. Sci. Technol. 30:1872-1881.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting Rainfall Erosion Losses – A Guide to Conservation Planning. U.S. Department of Agriculture. Agriculture Handbook No. 537.www.deq.virginia.gov/waterguidance/pdf/032012.pdf

Yagow, E. 1999. Unpublished monitoring data. Mountain Run TMDL Study.

Yagow, G., S. Mostaghimi, and T.A. Dillaha. 2002. GWLF model calibration for statewide NPS assessment. Virginia NPS pollutant load assessment methodology for 2002 and 2004 statewide NPS pollutant assessments. January 1 - March 31, 2002 Quarterly Report. Submitted to Virginia Department Conservation and Recreation, Division of Soil and Water Conservation, Richmond, Virginia.

Page intentionally blank

GLOSSARY

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies*. Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity*. The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota.

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Cause. 1. That which produces an effect (a general definition).
2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition).

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Concentration-response model. A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition*. Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES). *A permit issued by the EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. *The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Fate of pollutants. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Impairment. A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use.

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism*. An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause.

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor.

Infiltration capacity*. The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate*. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by the EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the* *conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metric ton (Mg or t). A unit of mass equivalent to 1,000 kilograms. An annual load of a pollutant is typically reported in metric tons per year (t/yr).

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Model. Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Most Probable Stressor(s): The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s).

Narrative criteria*. Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Non-Stressor(s): Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors.

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by the EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more* *than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Polycyclic aromatic hydrocarbons (**PAH**s) are chemical compounds that consist of fused aromatic rings and do not contain heteroatoms or carry substituents. PAHs occur in oil, coal, and tar deposits, and are produced as byproducts of fuel burning (whether fossil fuel or biomass). As a pollutant, they are of concern because some compounds have been identified as carcinogenic, mutagenic, and teratogenic.

Possible Stressor(s): Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors.

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works*. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period*. The time allowed for the public to express its views and concerns regarding action by the EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25th, 50th, and 75th percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50th quartile is also known as the median. The 25th and 75th quartiles are referred to as the lower and upper quartiles, respectively.

Rapid Bioassessment Protocol II (RBP II). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Reserve capacity*. Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration*. Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone*. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

***Roughness coefficient**. A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

***Runoff.** That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquatic systems as a result of erosion.

***Septic system**. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

***Sewer.** A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

***Simulation**. The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

***Slope.** The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor.

***Spatial segmentation**. A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 mL geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff*. Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. [2]

Surface area*. The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water*. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Technology-based standards. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Ton (T). A unit of measure of mass equivalent to 2,200 English lbs.

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Urban Runoff. Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

Wastewater treatment*. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality*. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based permit*. A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria*. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

Page intentionally blank

APPENDIX A

Frequency Analysis of Bacteria Data

Legend for Appendix A figures:

Samples meeting standard

Samples violating standard

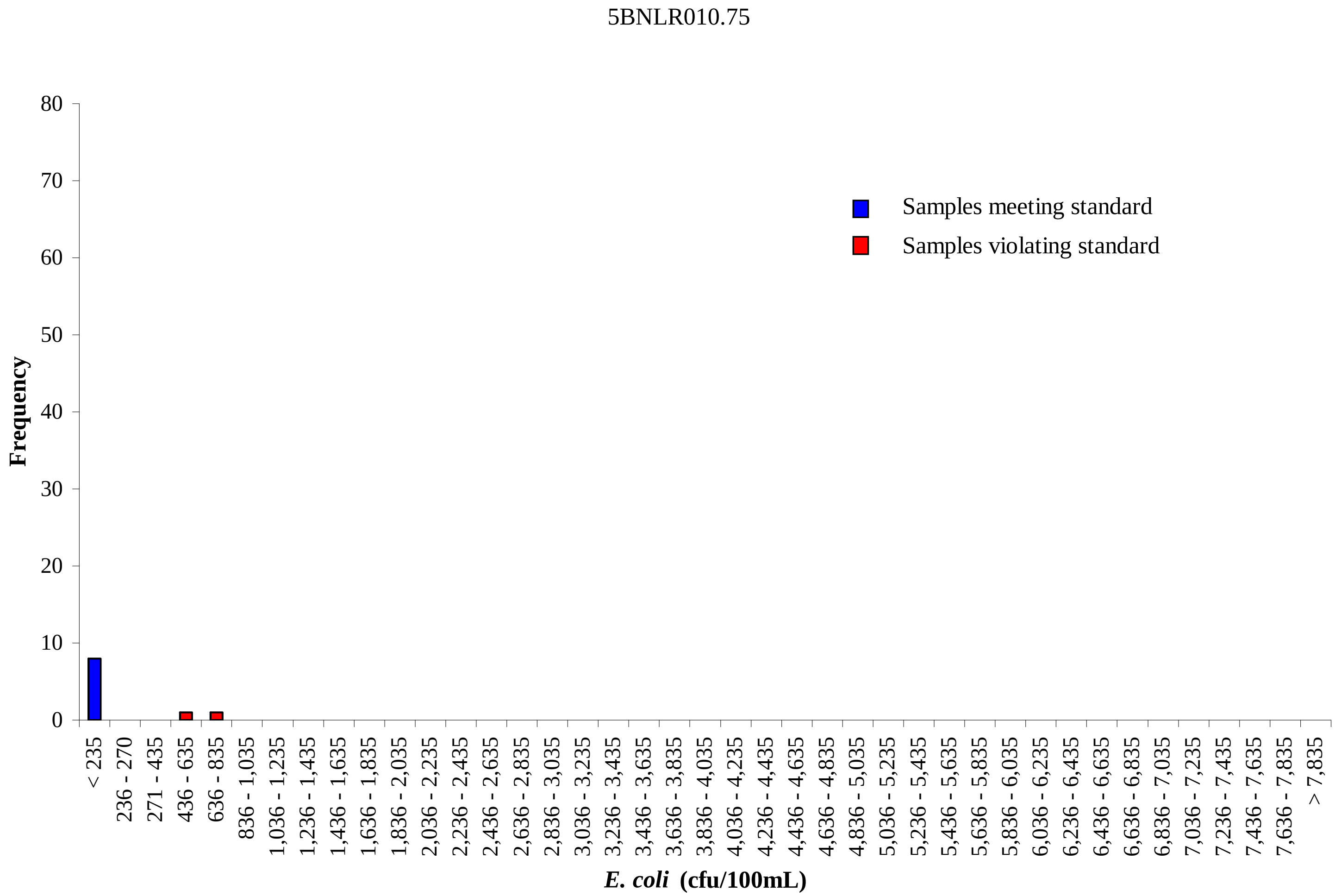

Figure A. 1 Frequency analysis of *E. coli* concentrations at station 5BNLR010.75 in North Landing River for the period from January 2000 to December 2006.

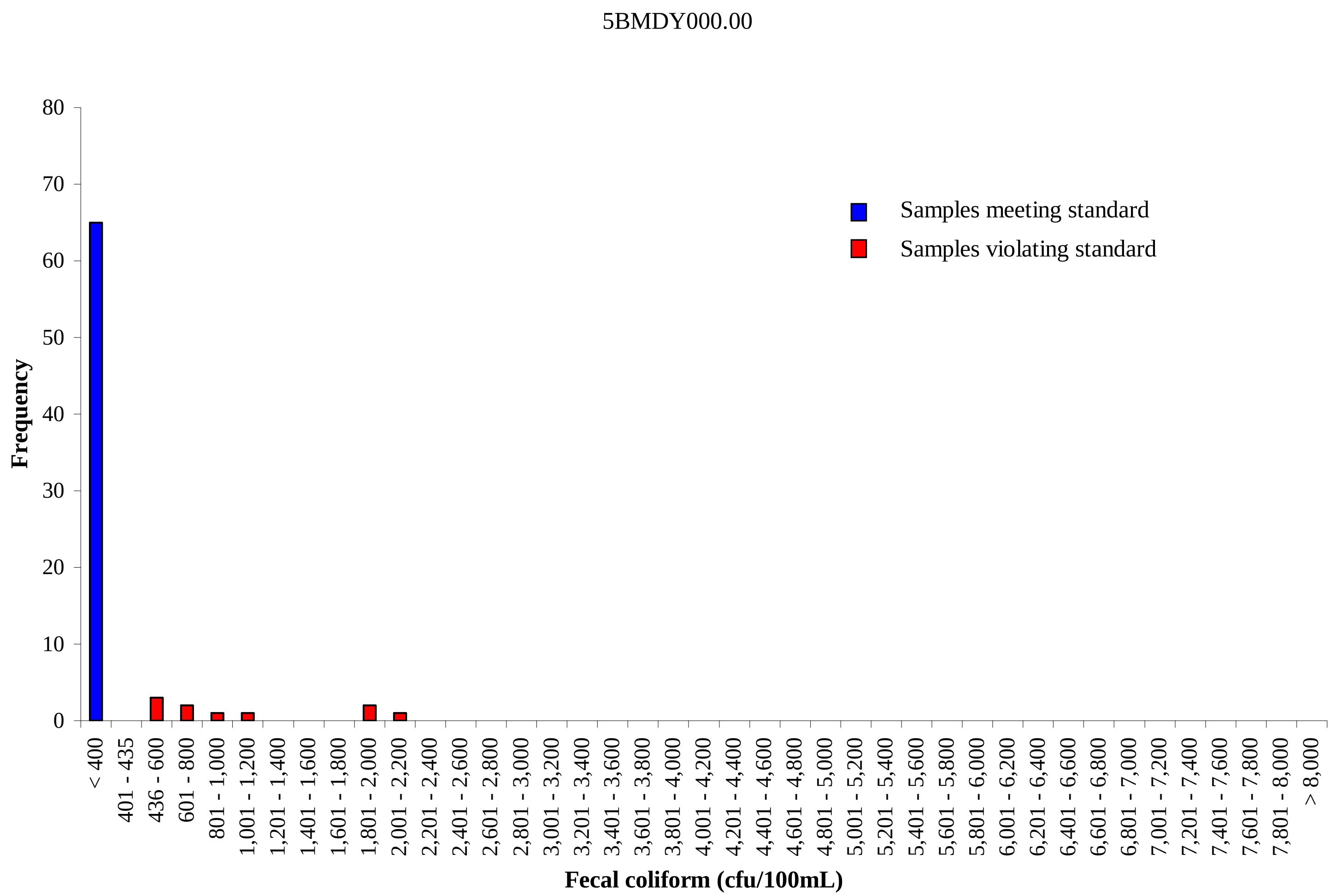

Figure A. 2 Frequency analysis of Fecal coliform concentrations at station 5BMDY000.00 in Muddy Creek for the period from July 2002 to March 2011.

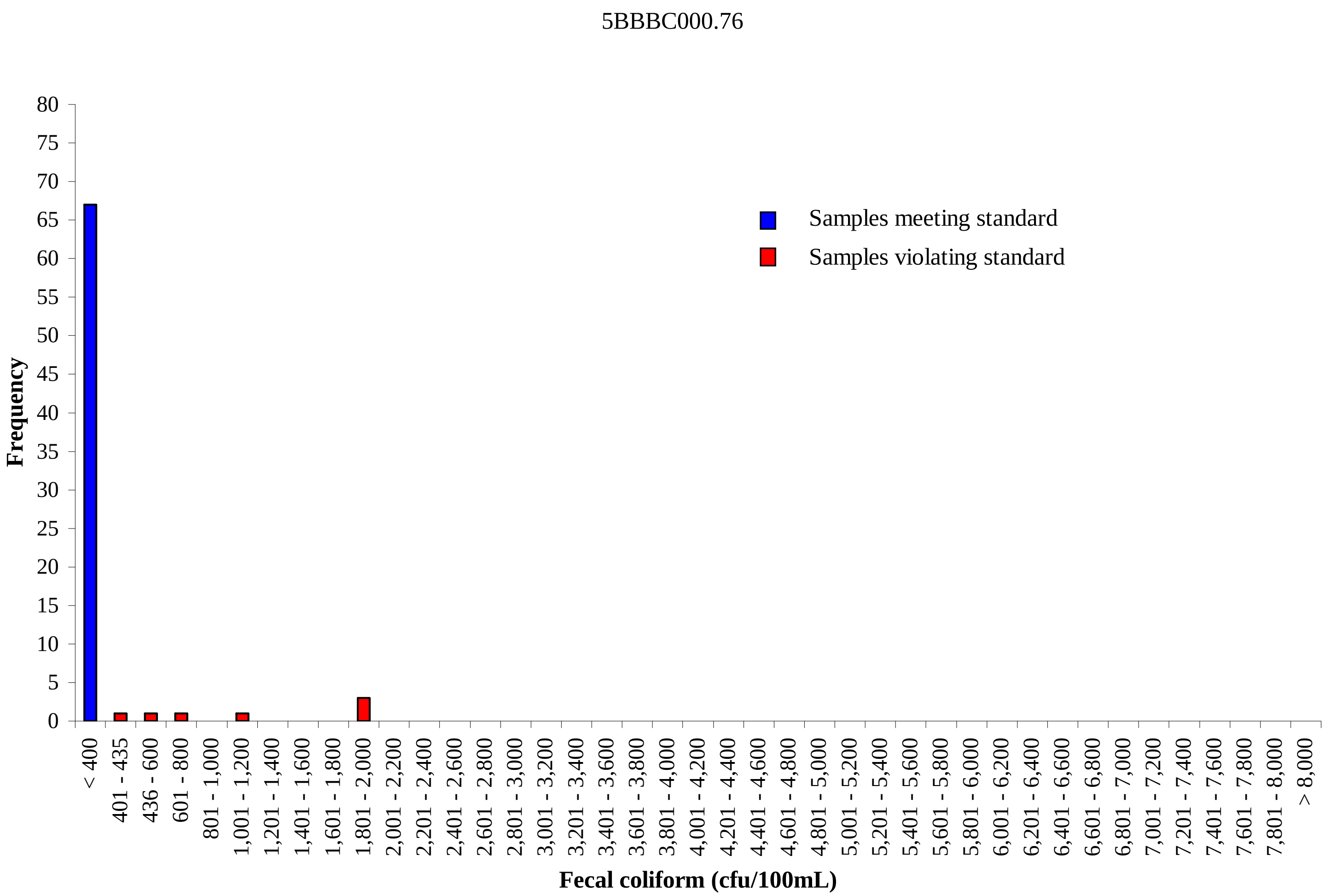

Figure A. 3 Frequency analysis of Fecal coliform concentrations at station 5BBC000.76 in Beggars Bridge Creek for the period from February 2000 to March 2011.

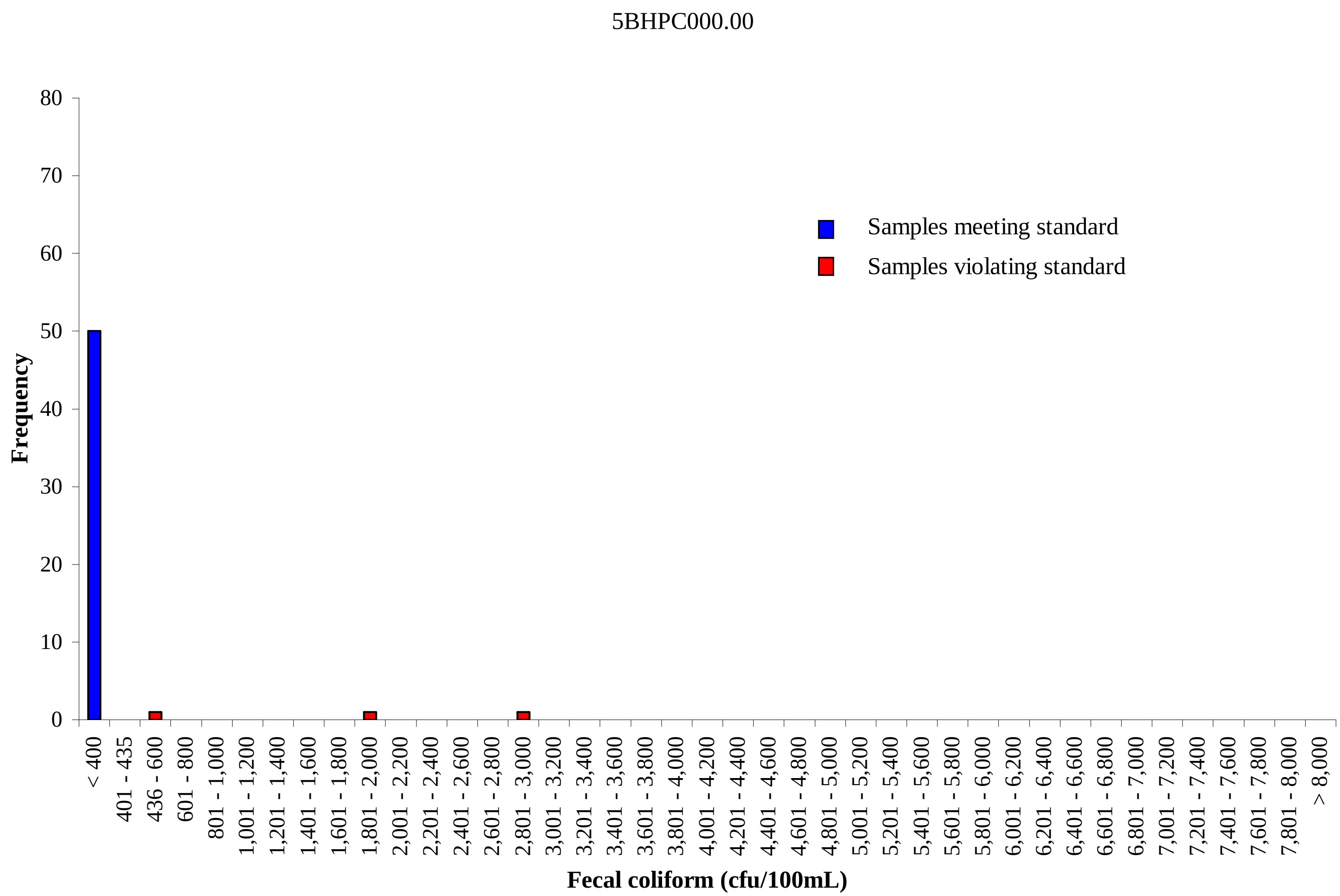

Figure A. 4 Frequency analysis of Fecal coliform concentrations at station 5BHPC000.00 in Lower Hellpoint Creek for the period from May 2000 to February 2011.

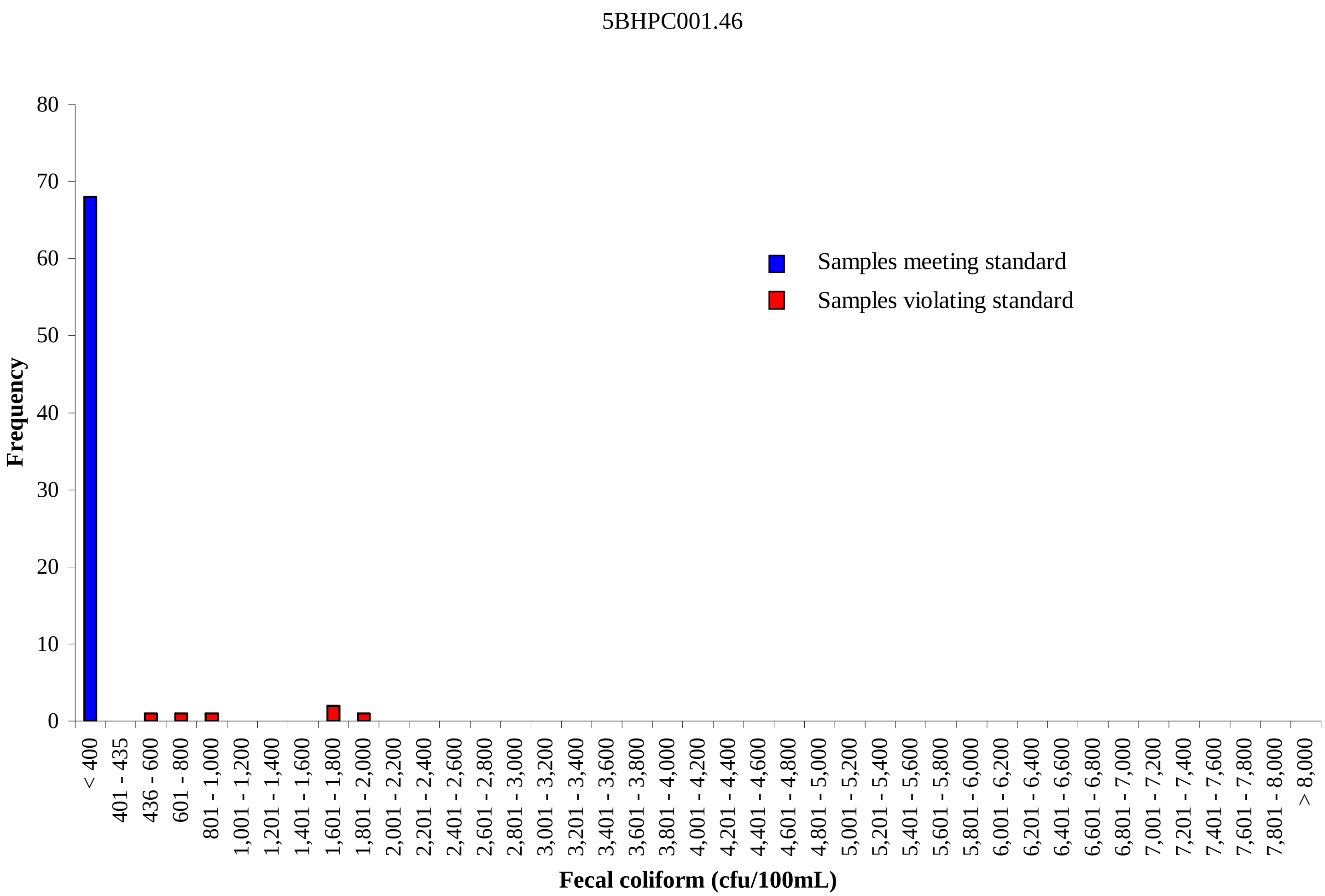

Figure A. 5 Frequency analysis of *E. coli* concentrations at station 5BHPC001.46 in Upper Hellpoint Creek for the period from February 2000 to March 2011.

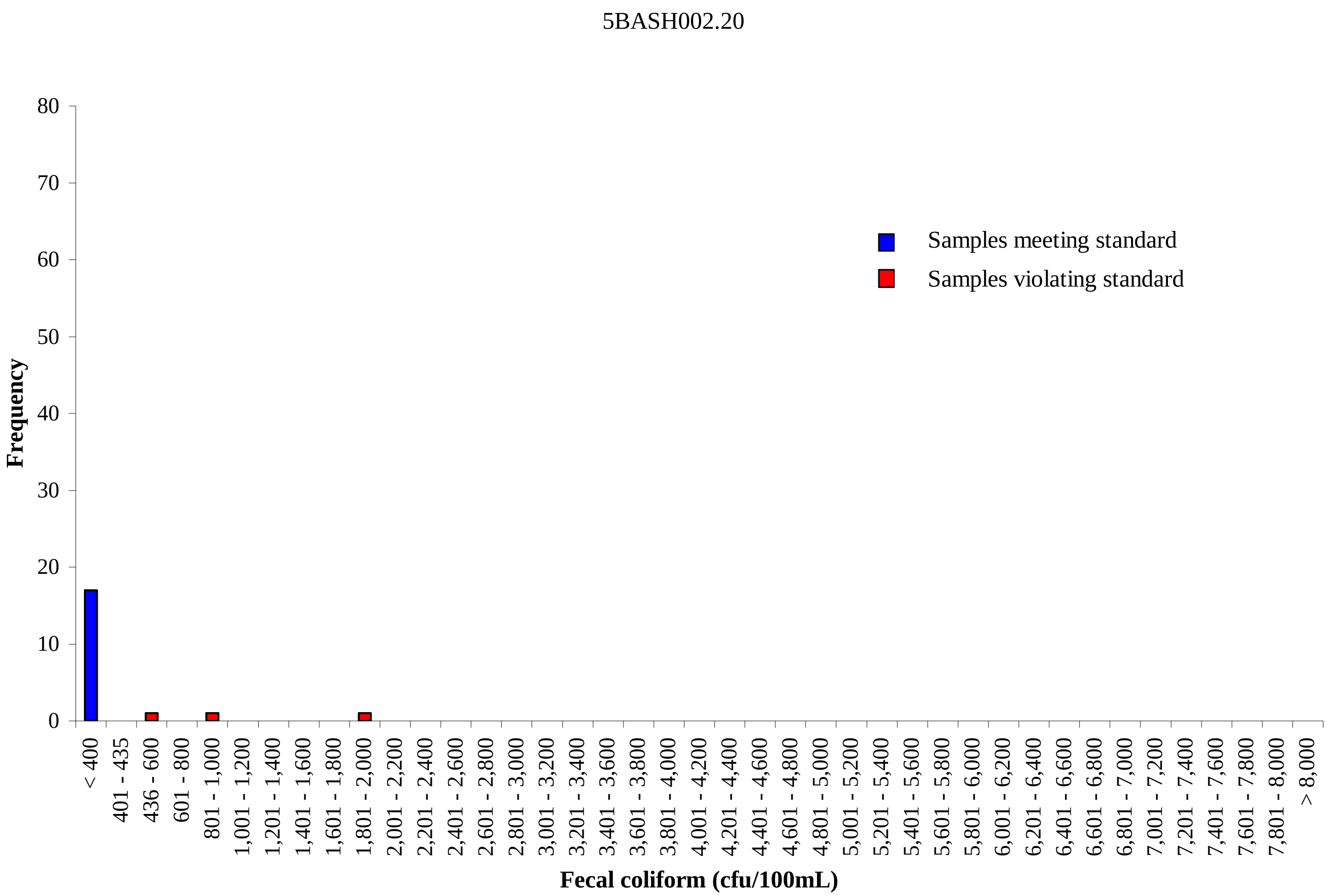

Figure A. 6 Frequency analysis of Fecal coliform concentrations at station 5BASH002.20 in Ashville Bridge Creek for the period from May 2003 to September 2006.

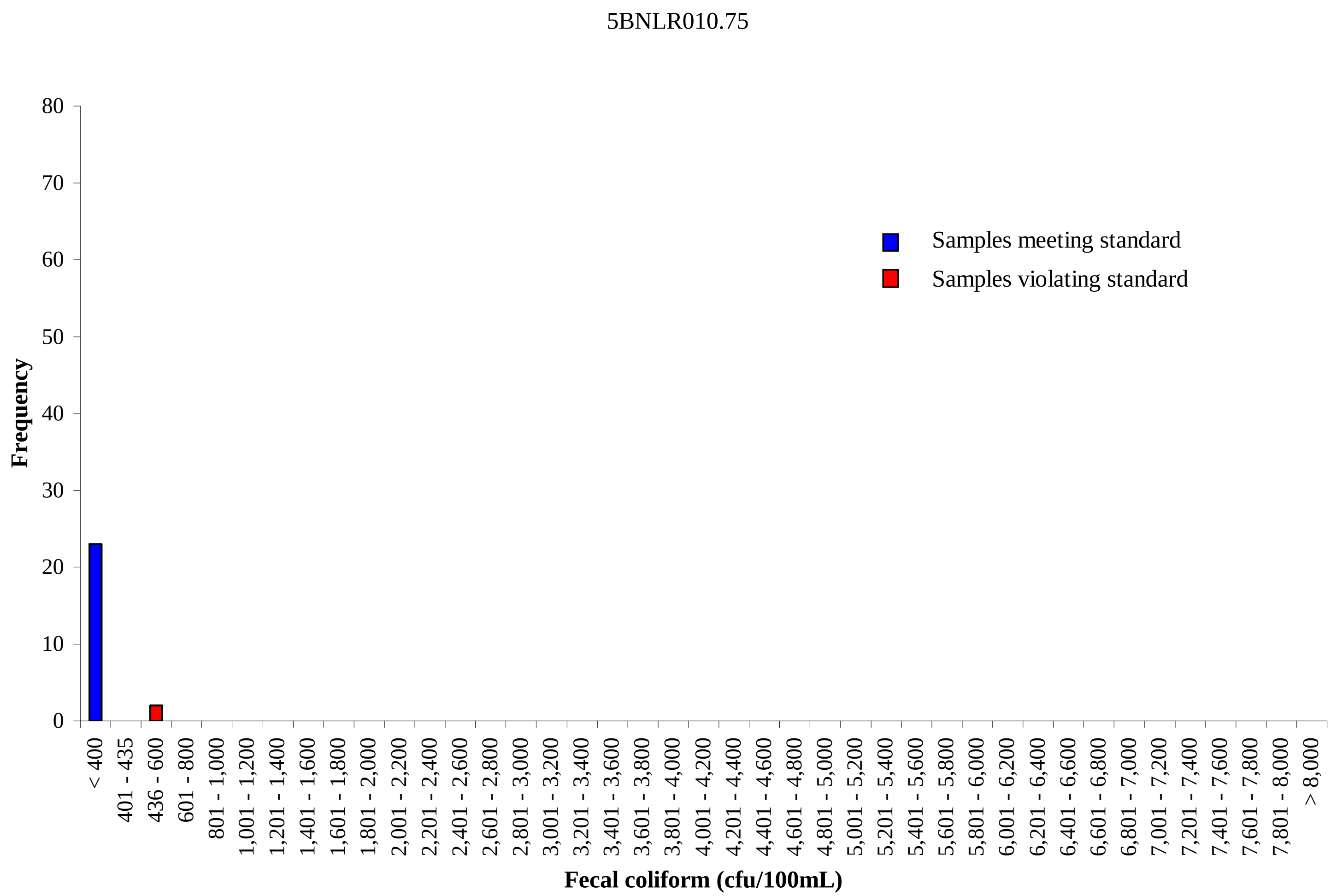

Figure A. 7 Frequency analysis of Fecal coliform concentrations at station 5BNLR010.75 in North Landing River for the period from January 2000 to December 2006.

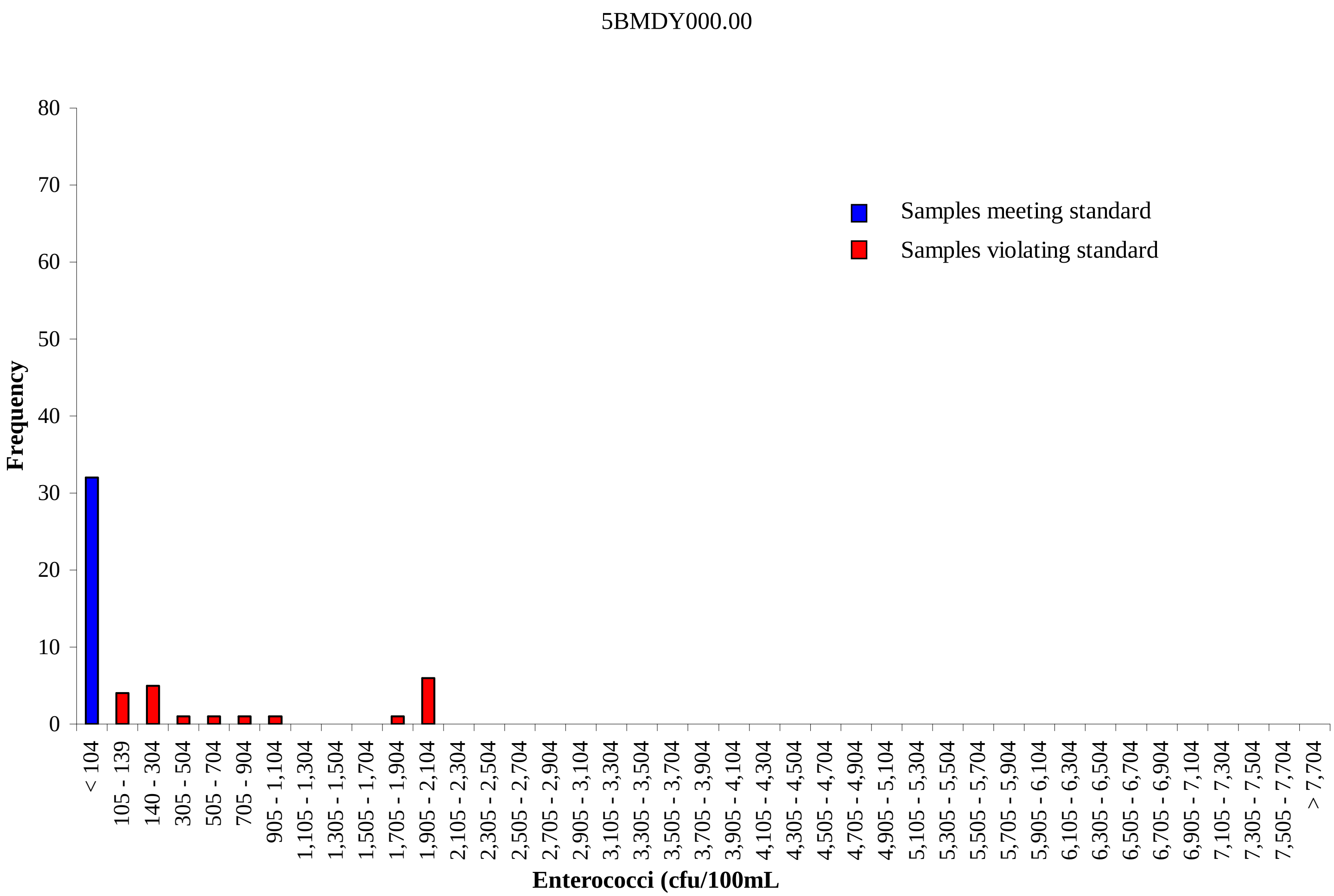

Figure A. 8 Frequency analysis of *enterococci* concentrations at station 5BMDD000.00 in Muddy Creek for the period from February 2000 to March 2011.

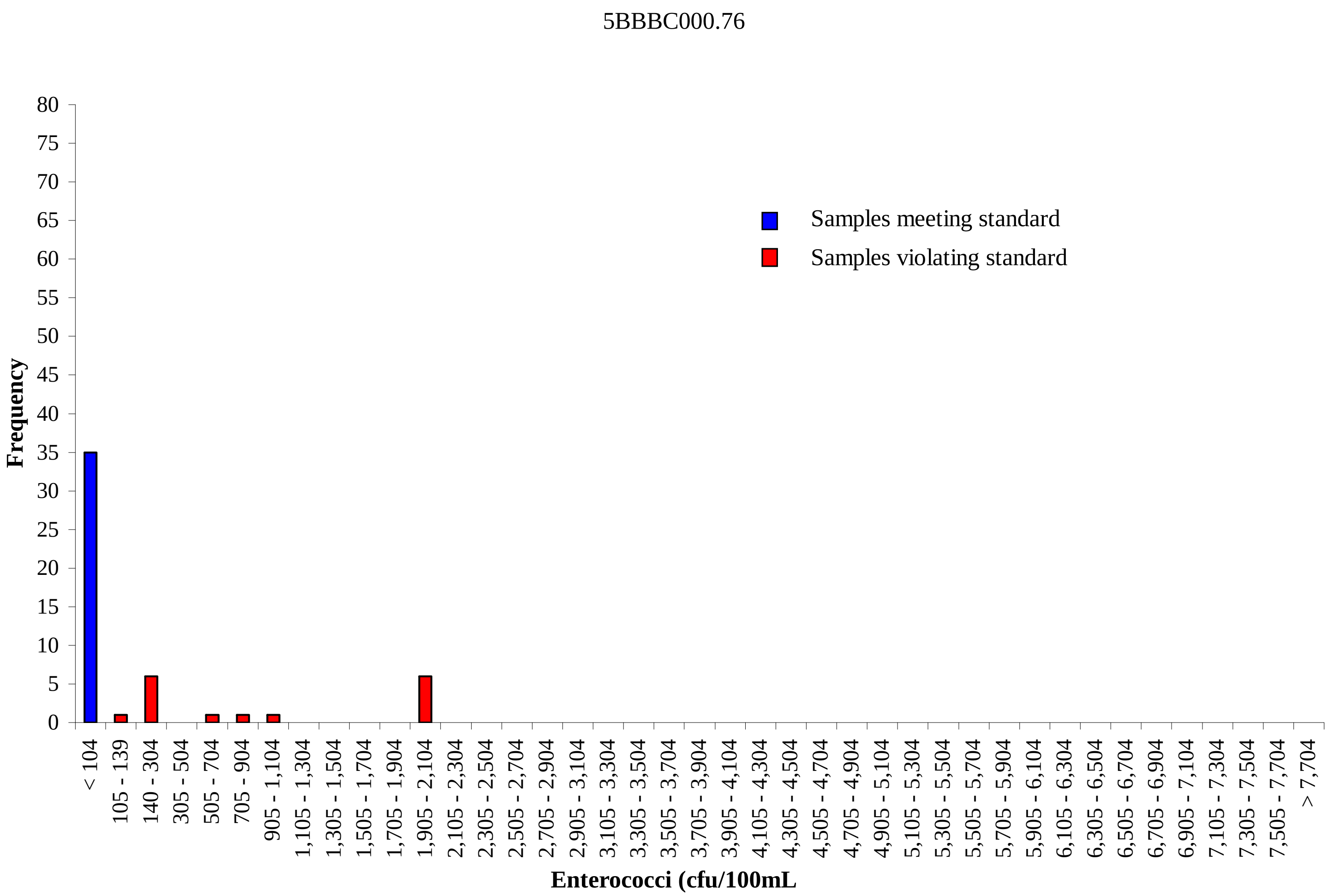

Figure A. 9 Frequency analysis of *enterococci* concentrations at station 5BBBC000.76 in Beggars Bridge Creek for the period from February 2000 to March 2011.

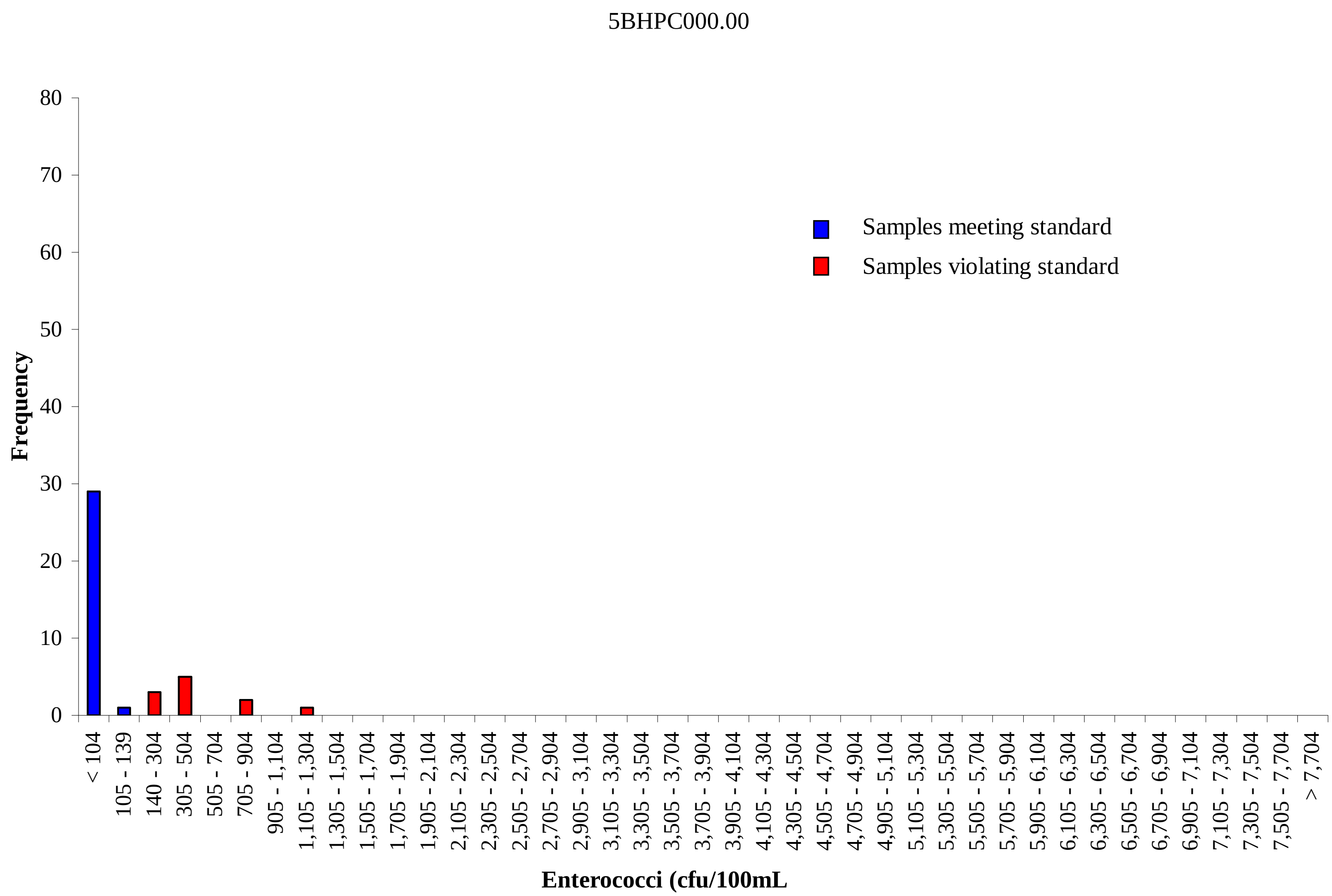

Figure A. 10 Frequency analysis of *enterococci* concentrations at station 5BHPC000.00 in the Lower Hell Point Creek for the period from February 2000 to March 2011.

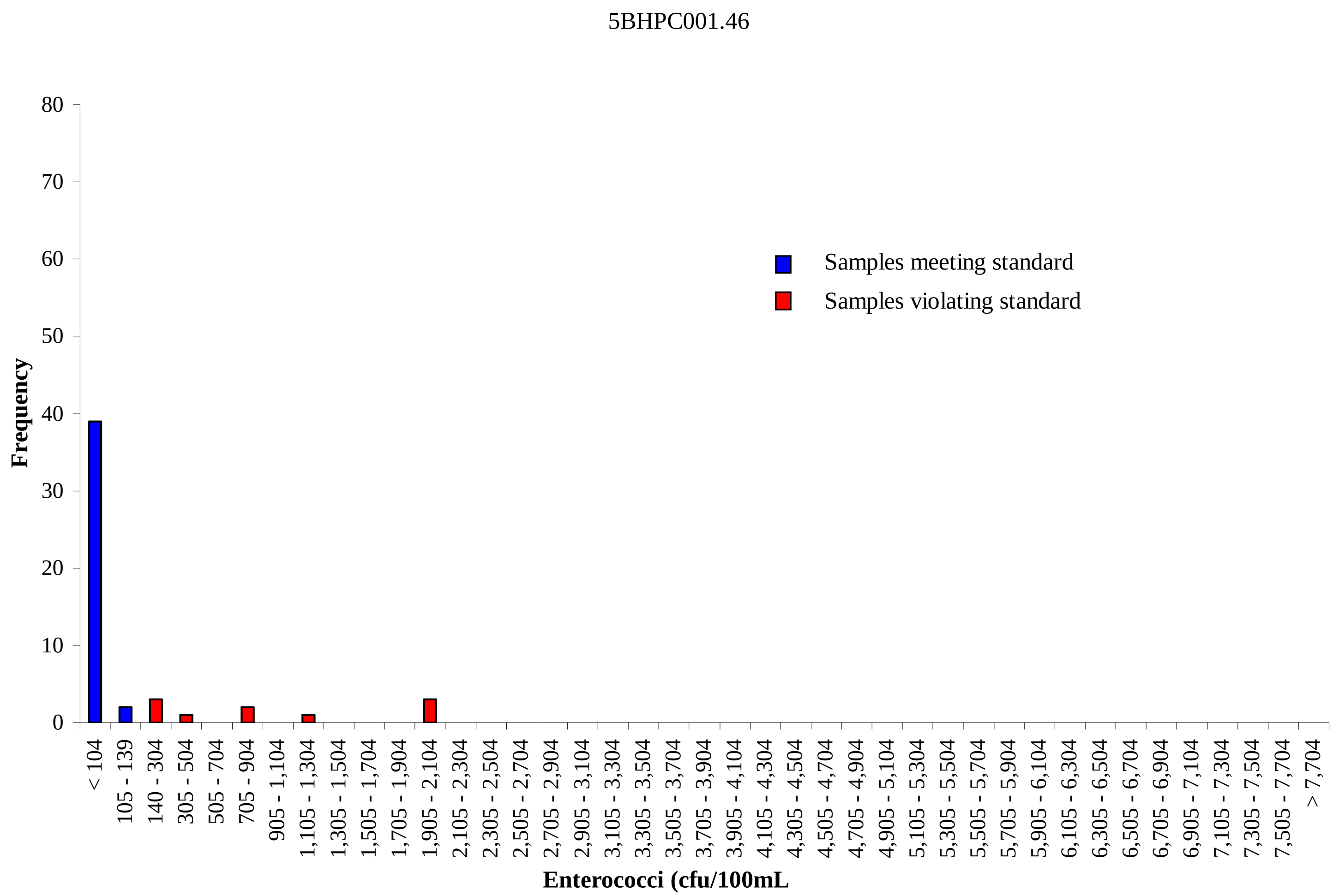

Figure A. 11 Frequency analysis of *enterococci* concentrations at station 5BHPC001.46 in the Upper Hell Point Creek for the period from February 2000 to March 2011.

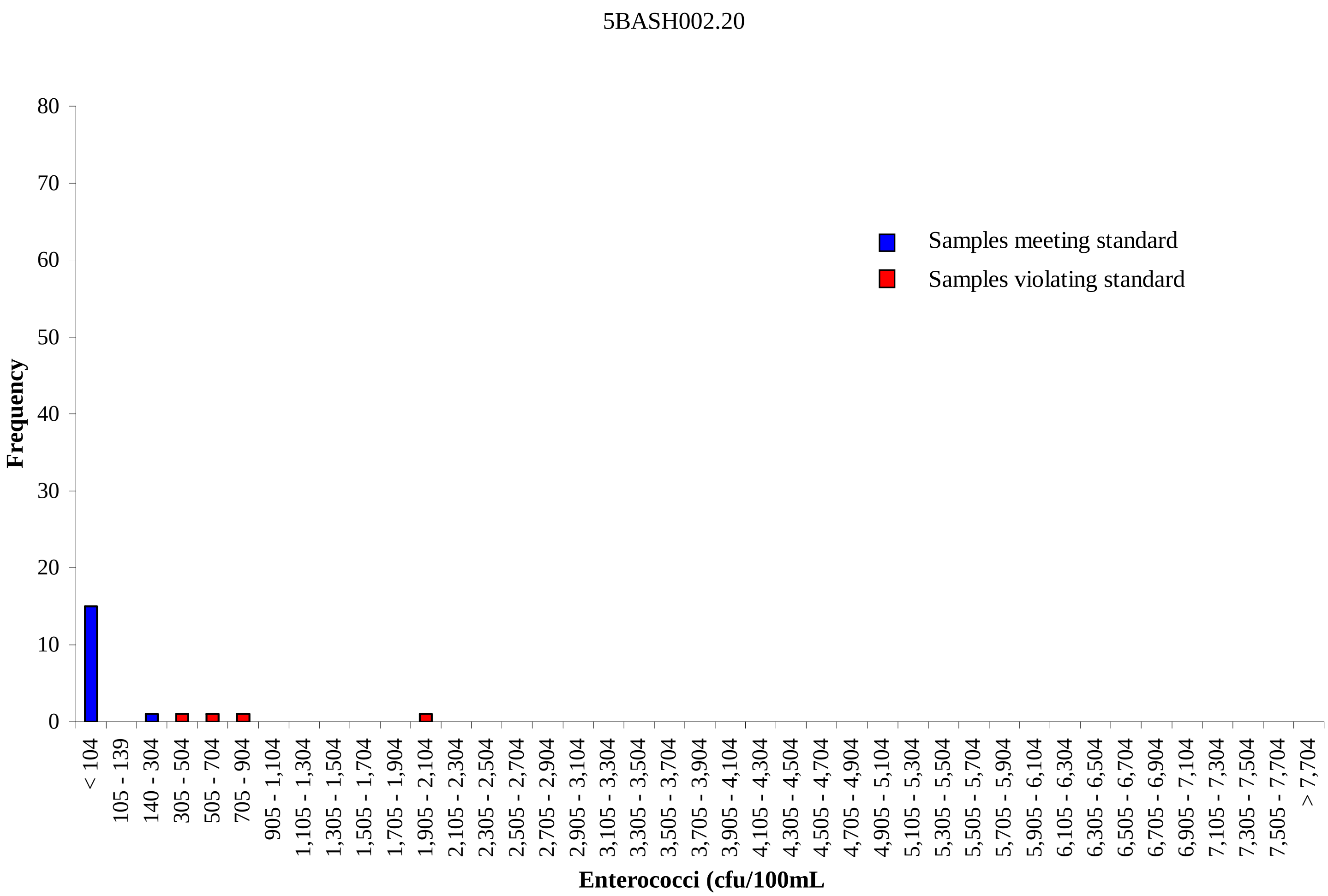

Figure A. 12 Frequency analysis of *enterococci* concentrations at station 5BASH002.20 in the Ashville Bridge Creek for the period from May 2003 to September 2006.

Page intentionally blank

APPENDIX B

Bacteria Modeling Procedure: Linking the Sources to the Endpoint

Bacteria Modeling Procedure:Linking the Sources to the Endpoint

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs in the study area, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify the accuracy of the relationships developed through modeling. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality.

Modeling Free-flowing Impairments

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate stream flow, overland runoff and to perform bacteria TMDL allocations.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

The HSPF model is a continuous simulation model that can account for nonpoint source (NPS) pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

Modeling the Tidal Impairment

The Steady State Tidal Prism Model, which is used by VADEQ for modeling tidally impacted waterbodies, was implemented within the HSPF framework to model the tidally influenced impairments in conjunction with lateral free-flowing. MapTech's implementation of the Tidal Prism Model uses the same basic principle of a control volume with ebb and flood tides based on monitored tide data and bathymetry. However, die-off and mixing are controlled within HSPF. This results in a time series of concentration within the impacted waterbodies.

Model Setup

Daily precipitation data was available near the study area at the Wallaceton Lk Drummond NCDC COOP station # 448837, Suffolk Lake Kilby NCDC COOP station #448192, and Norfolk South NCDC COOP station # 446147.

Subwatersheds

To adequately represent the spatial variation in the watershed, the study area was divided into 11 (eleven) subwatersheds (**Figure B. 1**). Subwatershed 1 through 4 contain the impairments with violations of the *E. coli* standard while the remaining subwatersheds contain the impairments violating the *enterococcci* standard. The rationale for choosing these subwatersheds was based on the availability of water quality and flow data, the stream network configuration, location of impairments, and the limitations of the HSPF model.

Figure B.1 shows all subwatersheds, which were used to achieve the unified model. **Table B. 1** notes the subwatersheds contained within each impairment, the impaired stream segments, and the outlet subwatershed for each impairment.

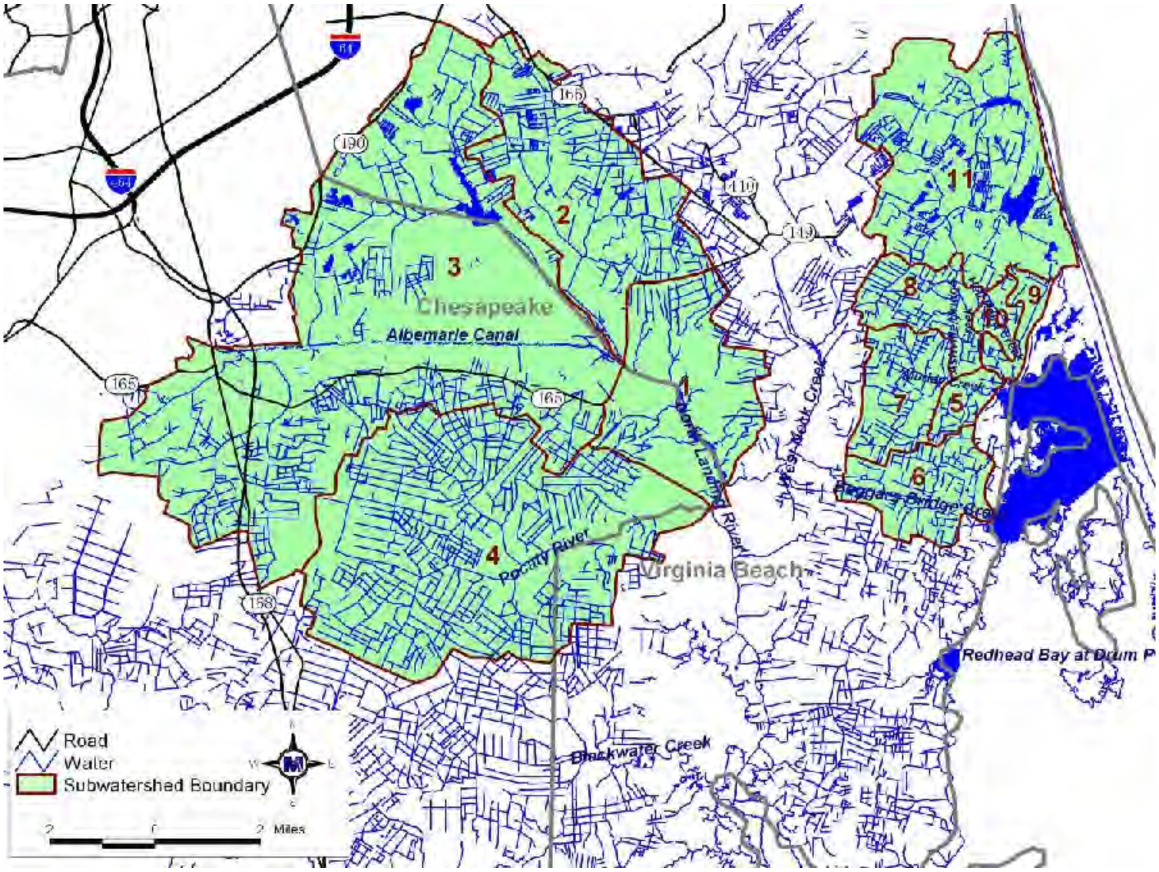

Figure B. 1 All subwatersheds delineated for modeling in the study area.

Table B. 1 Impairment groups and subwatersheds within the study area.

Impairment	Impaired Subwatershed(s)	Outlet	Contributing Subwatersheds
North Landing River VAT-K41R_NLR03A06	1	1	1,2,3
Pocaty River VAT-K41R_PCT01A02	4	4	4
Beggars Bridge Creek VAT-K42E_BBC01A04	6	6	6
Hell Point Creek – Upper + Lower VAT-K42E_HPC01A00 VAT-K42E_HPC02A04	9,10	9	9,10,11
Ashville Bridge Creek / Muddy Creek VAT-K42E_ASH01A06 VAT-K42E_MDY01A04	5,8	5	5,7,8

In an effort to standardize modeling procedures across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

Land Use / Land Cover

Ten land uses were identified in the watershed. These land uses were obtained by merging different sources including the MRLC (2006) land use grid, and aerial photography of the region. Pasture lands adjacent to streams were separated into an individual land use resulting in two types of pasture lands (pasture and livestock access). The ten land use types are given in **Table B. 2**. Within each subwatershed, up to the ten land use types were represented. Each land use in each subwatershed has hydrologic parameters (*e.g.,* average slope length) and pollutant behavior parameters (*e.g., E. coli* accumulation rate) associated with it. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in four IMPLND types, while there are nine PERLND types, each with parameters describing a particular land use. The impervious fraction was obtained from the 2006 NLCD data. Some IMPLND and PERLND parameters (*e.g.,* slope length) vary with the particular subwatershed in which they are located. Others vary with the season (*e.g.,* upper zone storage) to account for plant growth, die-off, and removal.

Table B. 2 shows the percentage pervious for each land use as used in modeling the study area. The percentage pervious was obtained from the 2006 NLCD data by land use / land cover. **Table B. 3** shows the breakdown of land uses within the drainage area.

Table B. 2 Consolidated land use categories for the study area used in HSPF modeling.

TMDL Land use Categories	Pervious / Impervious (%)
Barren	Pervious (93%) Impervious (7%)
Commercial	Pervious (30%) Impervious (70%)
Cropland	Pervious (100%)
Residential	Pervious (65%) Impervious (35%)
Open Space	Pervious (92%) Impervious (8%)
Forest	Pervious (100%)
Livestock Access	Pervious (100%)
Pasture	Pervious (100%)
Water	Pervious (100%)
Wetland	Pervious (100%)

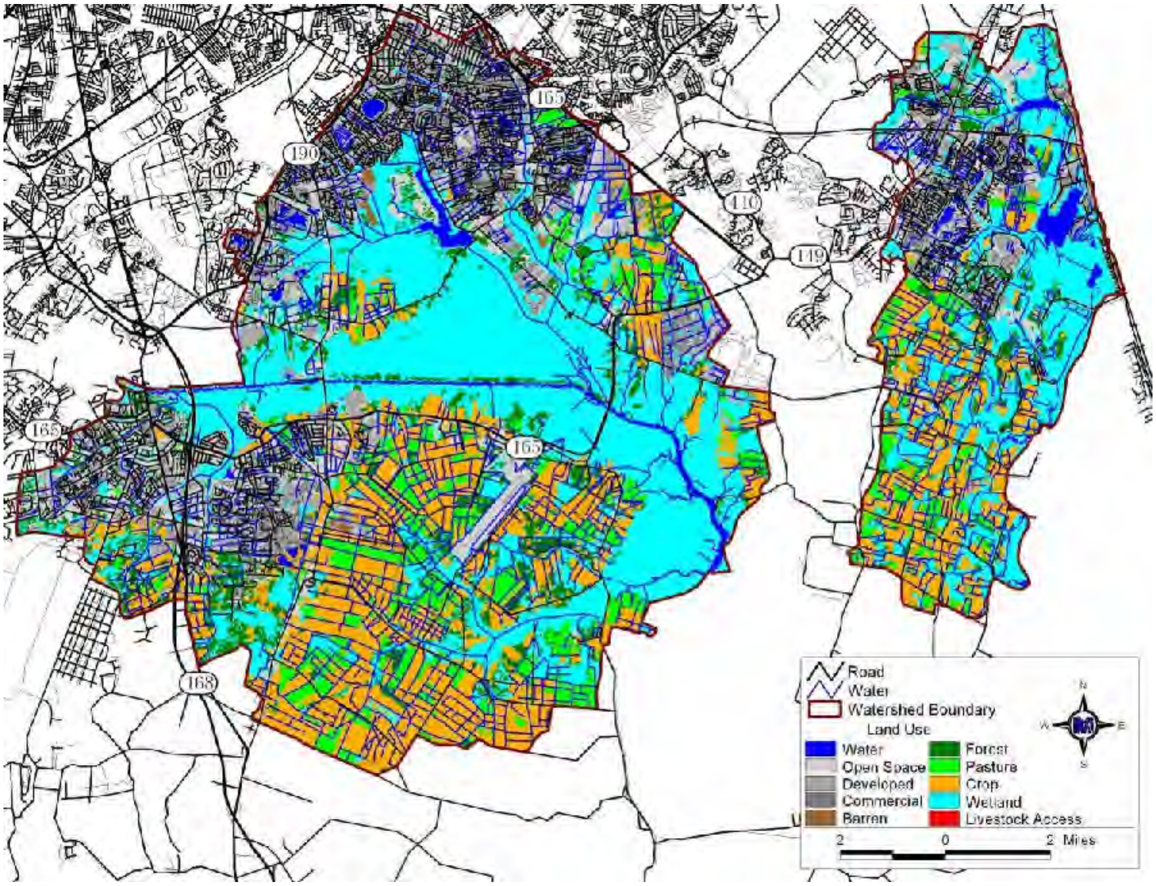

Figure B. 2 Land uses in the study area watershed.

Table B. 3 Area of land use types in acres in the study area.

Impairment	Barren	Comm.	Res.	Cropland	Forest	LAX	Open Space	Pasture	Water	Wetland	Total Acres
North Landing River VAT-K41R_NLR03A06	128.64	211.32	9,585.83	3,774.62	3,088.40	104.39	7,132.20	1,243.37	14,810.71	1,721.48	41,800.96
Pocaty River VAT-K41R_PCT01A02	37	8.89	224.51	7,441.46	1,391.11	186.43	1,072.68	2,400.38	3,674.27	525.44	16,962.17
Beggars Bridge Creek VAT-K42E_BBC01A04	0	0	14.1	1,196.98	134.36	24.22	92.97	287.19	851.27	78.23	2,679.32
Hell Point Creek – Lower + Upper VAT-K42E_HPC02A04 VAT-K42E_HPC01A00	20.47	156.2	2,762.23	433.8	648.39	21.84	1,719.38	177.68	3,705.84	700.18	10,346.01
Ashville Bridge Creek / Muddy Creek VAT-K42E_ASH01A06 VAT-K42E_MDY01A04	0	0	139.27	2,122.49	402.12	49.16	263.71	528.85	1,444.71	176.22	5,126.53

Die-off of fecal bacteria can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (*i.e.,* dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal bacteria entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.,* stream geometry and resistance to flow). This data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and discharge (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume in the reach, and is reported in acre-feet. The discharge is simply the stream outflow, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2013) and Digital Elevation Models (DEM) data was used. The NRCS has developed empirical formulas for estimating stream top width, cross-sectional area, average depth, and flow rate, at bank-full depth as functions of the drainage area for regions of the United States. Appropriate equations were selected based on the geographic location of the watershed. Using these NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams at each subwatershed outlet. A profile perpendicular to the channel was generated showing the stream profile height with distance for each subwatershed outlet (**Figure B. 3**).

Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths taken from the profile. An example of an F-table used in HSPF is shown in **Table B. 4**.

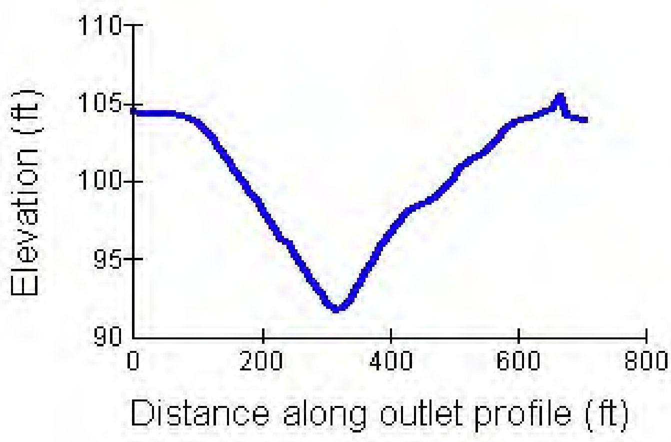

Figure B. 3 Stream profile representation in HSPF.

Table B. 4 Example of an F-table calculated for the HSPF model.

Depth (ft)	**Area (ac)**	**Volume (ac-ft)**	**Outflow (ft^3/s)**
0	0	0	0
3.28	0.71	1.41	17.07
6.56	1.89	5.15	45.23
9.84	2.54	12.18	85.02
13.12	4.77	24.80	152.82
16.40	56.55	77.51	637.72
19.68	1,047.22	1,635.10	18,846.85
22.96	2,875.31	7,405.99	69,827.77
26.24	3,495.32	18,464.40	133,806.76
29.52	4,426.89	31,720.10	160,393.97

Selection of Representative Modeling Periods

The selection of a representative modeling period takes into consideration historical records of precipitation, flow, and water quality. Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions.

Limited observed flow data were available and therefore, paired watershed approach was used to adjust the hydrological parameters within the study area. Initial estimates of these parameters were obtained and then adjusted based on final calibrated hydrologic parameters within Nansemond River watershed. Water quality calibration periods were based on availability of observed water quality data collected by VADEQ.

During the Nansemond River analysis, the resulting period chosen for hydrologic calibration was 10/1/1997 to 9/30/2002. For hydrologic model validation, the period selected was 10/1/1991 to 9/30/1996.

For water quality modeling, data availability was the governing factor in the choice of calibration and validation. The period containing the greatest amount of monitored data dispersed over the most stations, and for which the assessment of potential sources was most accurate (10/1/2003 to 9/30/2009), was chosen as the calibration/validation period. The period most representative of the watershed (10/1/1997 to 9/30/2002) was chosen as the allocation period to ensure that the critical conditions in the watershed were being simulated during water quality allocations.

Bacteria TMDL Critical Condition

EPA regulations at 40 CFR 130.7 (c)(1) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the study area is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken in order to meet water quality standards. *E. coli* and *enterococci* bacteria sources within the study area are attributed to both point and nonpoint sources. Critical conditions for waters impacted by land-based nonpoint sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include nonpoint sources that are not precipitation driven (*e.g.*, fecal deposition to stream).

A description of the data used in these analyses is shown in Chapter 2. Graphical analyses of fecal bacteria concentrations and flow duration intervals showed that water quality standard violations occurred at nearly every flow interval at the monitoring locations within the study area (**Figure B. 4 – Figure B. 9**). This demonstrates that all flow regimes should be represented in the allocation modeling time period. Therefore, to account for critical conditions for bacteria in the watershed, the allocation modeling period is selected to coincide with the hydrologic calibration period (1997 to 2002) since this period was selected to include both low and high flow conditions.

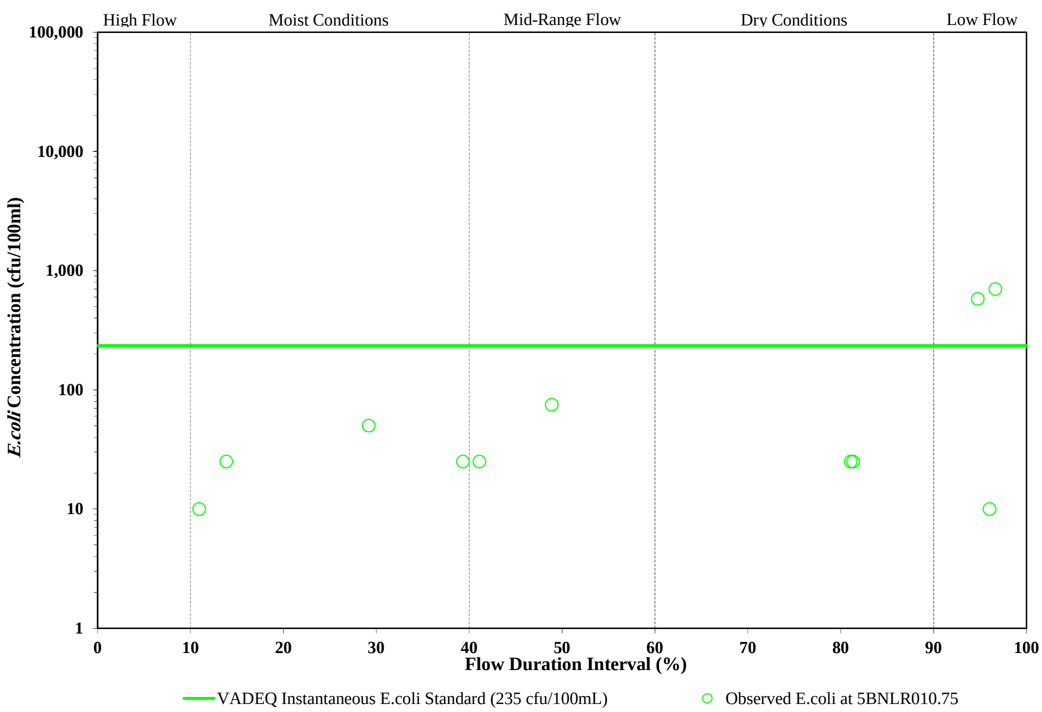

Figure B. 4 ***E. coli*** **concentrations-duration at 6BNLR010.75 on North Landing River.**

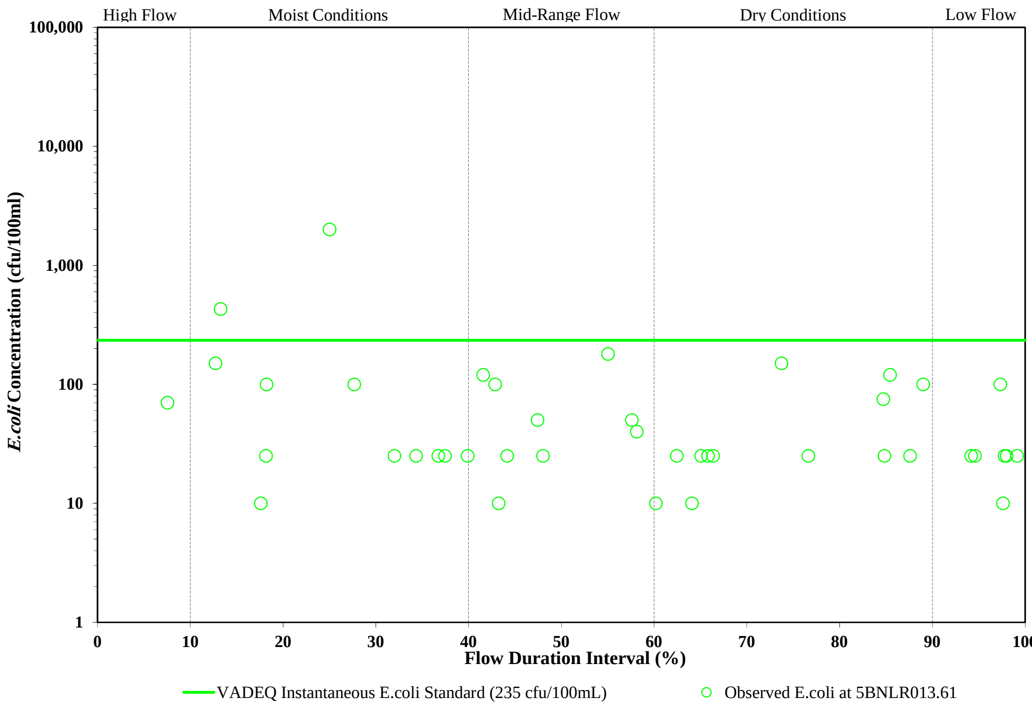

Figure B. 5 ***E. coli*** **concentrations-duration at 5BNLR013.61 on North Landing River.**

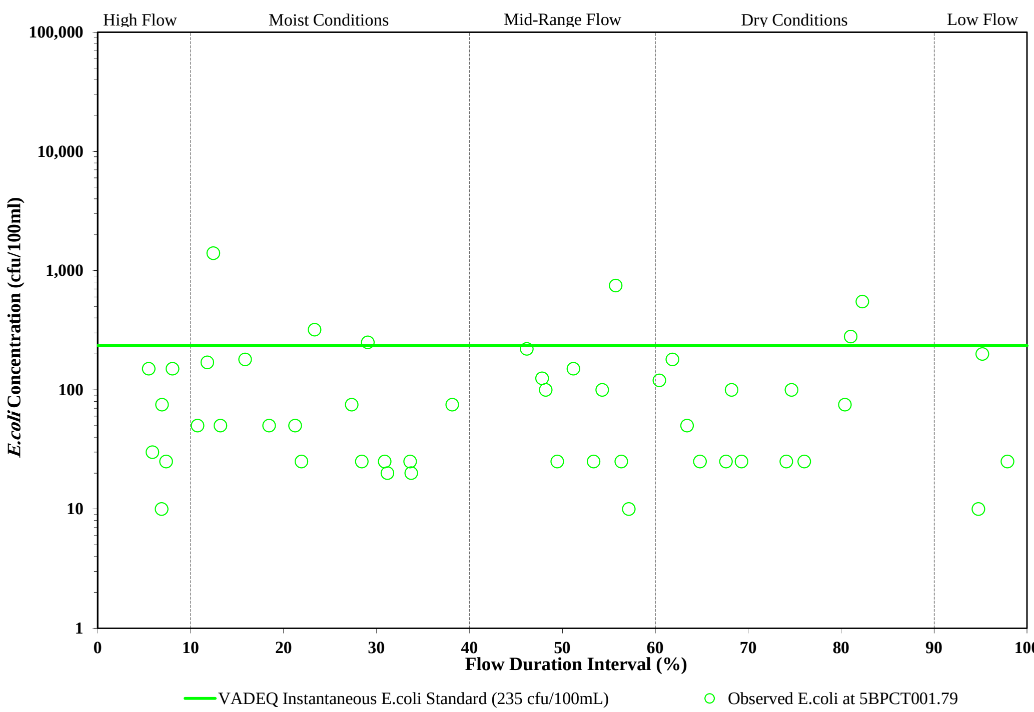

Figure B. 6 ***E. coli*** **concentrations-duration at 5BPCT001.79 on Pocaty River.**

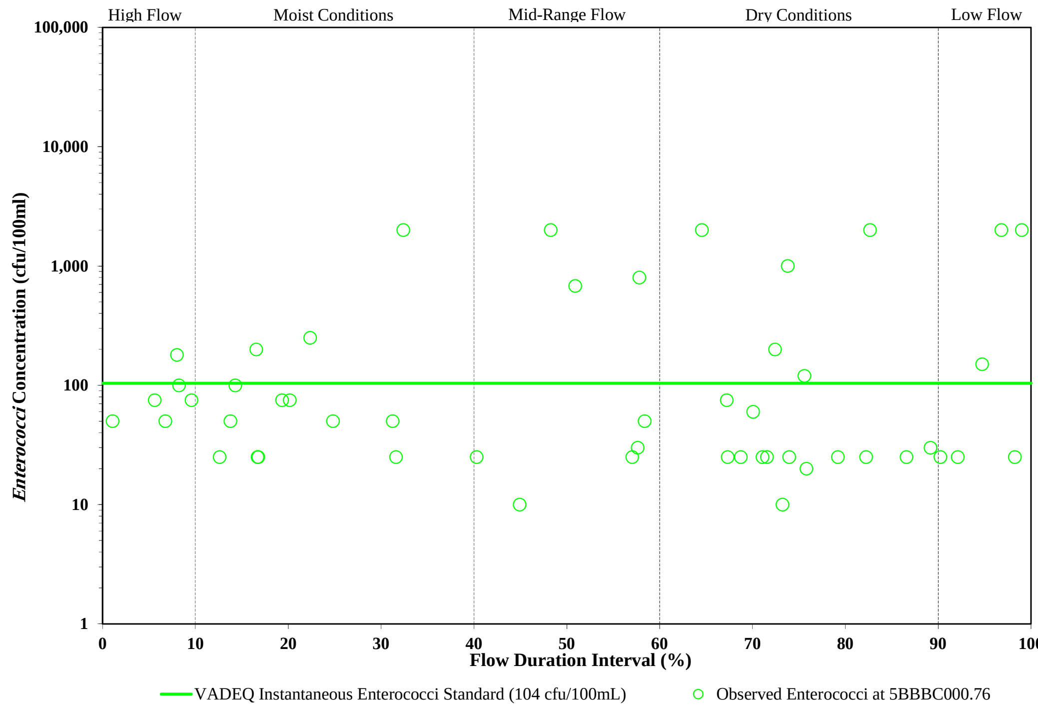

Figure B. 7 ***Enterococci* concentrations-duration at 5BBBC000.76 on Beggars Bridge Creek.**

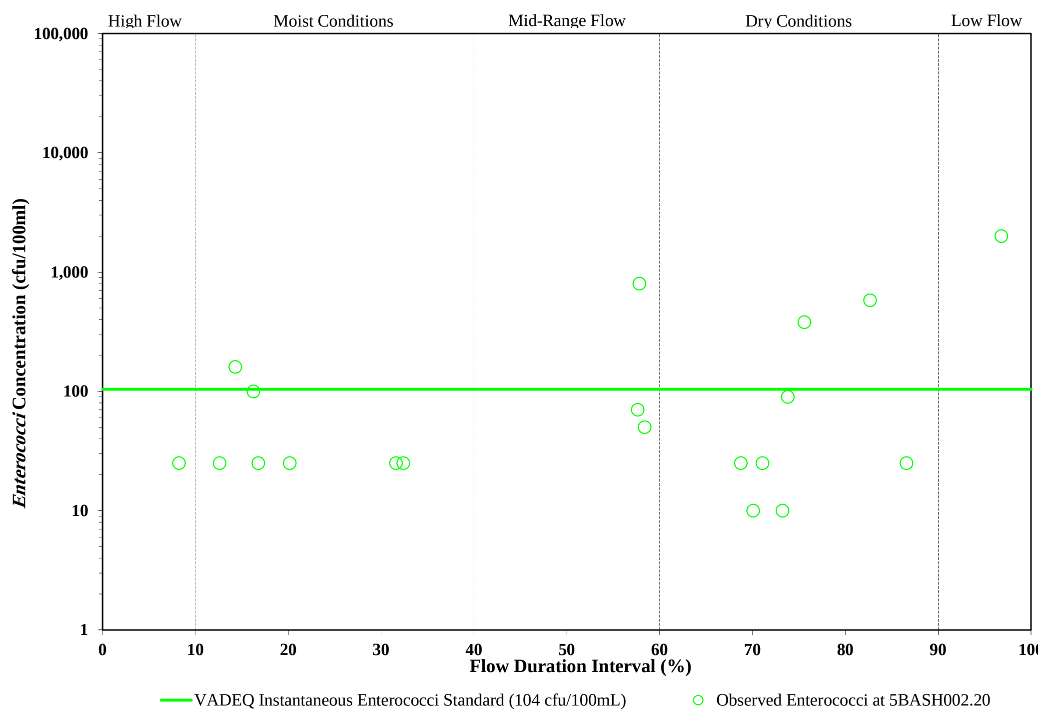

Figure B. 8 ***Enterococci* concentrations-duration at 5BASH002.20 on Ashville Bridge Creek.**

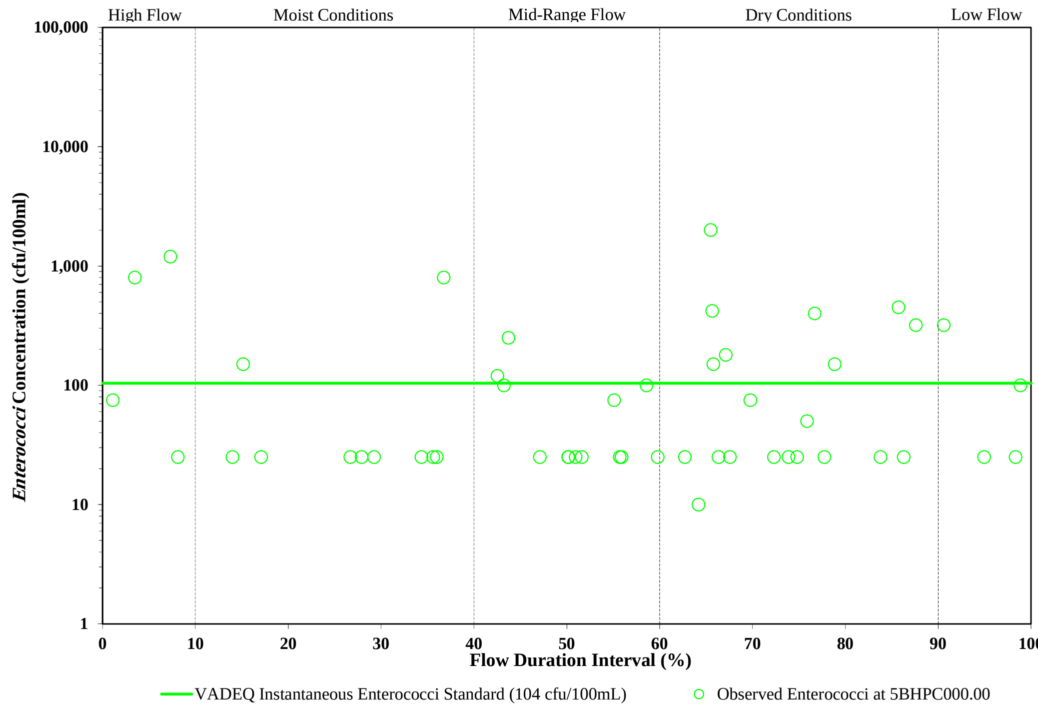

Figure B. 9 ***Enterococci* concentrations-duration at 5BHPC000.00 on Hell Point Creek.**

Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.*, animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Once in stream, die-off is represented by a first-order exponential equation.

Data were obtained for the appropriate timeframe for water quality calibration and validation. Data representing 2012 were used for the allocation runs in order to represent current conditions.

Permitted Sources

Table B. 5 shows the individual and domestic Virginia Pollutant Discharge Elimination System (VPDES) permits in the tudy area. The HRSD – Atlantic Sewage Treatment Plant has a design flow of approximately 36 million gallons per day but discharges to the atlantic Ocean and will not be enetred into the model nore will it be assigned a waste load allocation. When available, during water quality calibration and validation phase of the modeling effort, observed discharge rate and bacteria content data provided by DEQ was used. During the allocation phase of modeling, the design flow was used along with a fecal coliform concentration of 200 cfu/100 mL to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels (**Table B. 5**).

Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

Table B. 5 Flow rates and bacteria loads used to model VADEQ active permitted point sources in the study area.

VADEQ Permit Number	Facility Name	Allocation	
		Flow Rate (Million Gallon per Day)	Bacteria Concentration (cfu/100 mL)
			Fecal Coliform Geometric Mean Standard[1]
VA0062391	Indian Cove Resort Association Incorporated	0.038	200
VAG403053	True Way Evangelistic Church	0.00075	200
VAG403065	Battlefield Golf Club at Centerville	0. 00095	200
VAG403048	Private Residence	0.0005	200

[1] Fecal coliform standard is used since fecal colifom is modeled and not *E. coli* as explained in Chapter 5's introduction.

The MS4 loads are calculated as the loads coming from impervious surfaces within the MS4 permit boundaries after load allocation is completed. Source loads on contributing lands are identified and quantified. Once allocation is completed, the load coming from the impervious portion of the contributing lands is estimated and summed to represent the MS4 load.

Private Residential Sewage Treatment

The number of septic systems in the study area was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2010) with the subwatersheds. Initial estimates of total number of homes using septic systems were enhanced with county housing data when available and verified by state agencies (Section 3.2.1).

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. The initial estimates of the number of failing septic systems was based on the assumption that each septic systems fails, on average, once during an expected lifetime of 30 years. Resulting estimates were shared with regions Health Departments and feedback was obtained and used in adjusting numbers. During allocation runs, 96 homes were assumed to have septic syetms that are faling for part of the year and 13 homes were estimated to be using straight pipes (**Table 3.4**). The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months.

Straight pipes were estimated using 1990 U.S. Census Bureau block demographics. Ten percent of houses listed in the Census sewage disposal category “other means” were assumed to be disposing sewage via straight pipes. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. The loadings from straight pipes were modeled in the same manner as direct discharges to the stream.

Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock populations were estimated for each water quality modeling period (calibration/validation/allocation). The numbers are based on data provided by Virginia Agricultural Statistics (VASS), with values updated and discussed by VADCR, NRCS and SWCDs as well as taking into account growth rates in these counties as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 2005; VASS, 2012). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams. The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

Land Application of Collected Manure

The average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.2.4. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. Finally, values for the percentage of loafing lot waste collected were used to calculate the amount of waste available to be spread on pasture and cropland (**Table 3.10**). Stored waste was spread on pasture and cropland. It was assumed that 100% of land-applied waste is available for transport in surface runoff.

Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR (MapTech, 2002). The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horses, sheep) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land was area-weighted.

Direct Deposition to Streams

The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the "Modeling Cattle Stream Access" study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

Biosolids

Investigation of VADEQ data indicated that biosolids applications have occurred within the study area. Class B biosolids are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. Records of biosolids application location, timing and quantity were available, enabling the water quality modeling to be carried out in an “as applied” fashion, wherein the water quality model received land based inputs of biosolids loads on the day in which they actually occurred. During model runs, biosolids were modeled as having a fecal concentration of 157,835 cfu/g, the mean value of measured biosolids concentrations observed in several years of samples supplied by VADEQ for sources applied during 1999 to 2011. Applications were modeled as being spread onto the land surface over a six-hour period on the date of reported application. An assumption of proper application was made, wherein no biosolids were modeled as being spread in stream corridors.

Wildlife

For each species of wildlife, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.5). An example of one of these layers is shown in **Figure B. 10**. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the wasteload, fecal coliform densities, and number of animals for each species.

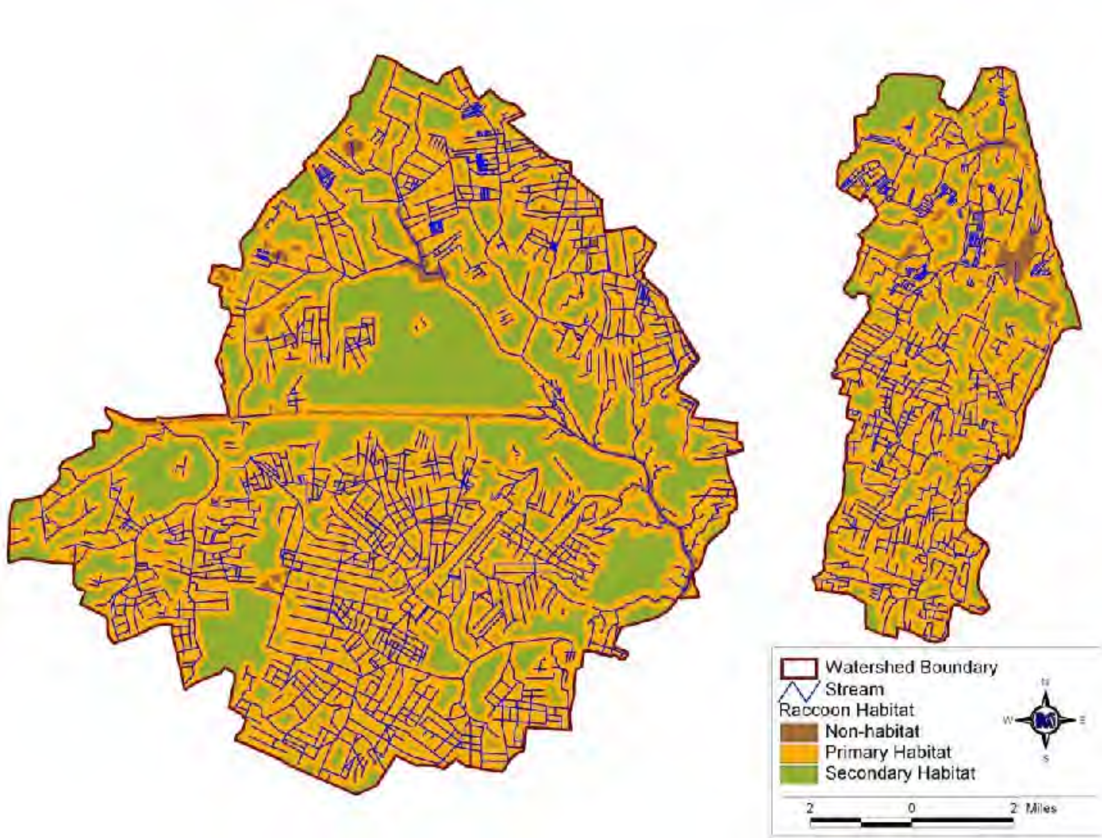

Figure B. 10 Example of raccoon habitat layer in the study area, as developed by MapTech.

For each species, a portion of the total wasteload was considered land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (**Table 3.15**). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams.

Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.2.3. Waste from pets was distributed on residential land uses. The number of households per subwatershed was taken from the 2010 Census (USCB, 2010). The number of animals per subwatershed was determined by multiplying the number of households by the pet population density. The amount of fecal coliform deposited daily by pets in each subwatershed was calculated by multiplying the wasteload, fecal coliform density, and number of animals for both cats and dogs. The wasteload was assumed not to vary seasonally. The populations of cats and dogs were projected to 2012.

Sensitivity Analysis

Sensitivity analyses are performed to determine a model's response to changes in certain parameters. This process involves changing a single parameter a certain percentage from a baseline value while holding all other parameters constant. This process is repeated for several parameters in order to gain a complete picture of the model's behavior. The information gained during sensitivity analysis can aid in model calibration, and it can also help to determine the potential effects of uncertainty in parameter estimation. Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads).

Hydrology Sensitivity Analysis

The HSPF parameters adjusted for the hydrologic sensitivity analysis are presented in **Table B. 6**, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, and the model was run for water years 1997-2002. Where an increase of 50% exceeded the maximum value for the parameters, the maximum value was used and the parameters increased over the base value were reported. The hydrologic quantities of greatest interest in a fecal coliform model are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of fecal coliforms from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration), and by UZSN (Upper Zone Storage), which governs surface transport, LZETP (Lower Zone Evapotranspiration), which affects soil moisture and AGWRC (Groundwater Recession Rate). Low flows are important in a water quality model because they control the level of dilution during dry periods.

Parameters with the greatest influence on low flows (as evidenced by their influence in the *Low Flows* and *Summer Flow Volume* statistics) were AGWRC (Groundwater Recession Rate), KVARY (Groundwater Recession Flow), and INFILT. The responses of these and other hydrologic outputs are reported in **Table B. 7**.

Table B. 6 HSPF base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	7.0
INFILT	Soil Infiltration Capacity	in/hr	0.0353 – 0.1326
BASETP	Base Flow Evapotranspiration	---	0.20 - 0.20
INTFW	Interflow Inflow	---	1.0 - 1.0
DEEPFR	Groundwater Inflow to Deep Recharge	---	0.1 - 0.1
AGWRC	Groundwater Recession rate	---	0.94
KVARY	Groundwater Recession Flow	1/in	1.0
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.01-0.2
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.28-0.70
MON-LZETP	Monthly Lower Zone Evapotranspiration	in	0.01-0.40

Table B. 7 HSPF Sensitivity analysis results for hydrologic model parameters for the study area.

Model Parameter	Parameter Change (%)	Percent Change in: Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume
AGWRC[1]	0.85	1.66	5.00	-37.60	0.28	2.61	1.57	3.20	2.57
AGWRC[1]	0.92	0.53	1.34	-11.33	0.13	0.55	0.59	1.09	0.91
AGWRC[1]	0.96	-0.72	-1.52	13.69	-0.36	-0.43	-0.98	-1.24	-1.49
AGWRC[1]	0.999	-11.12	-8.63	50.00	-18.24	-5.33	-8.79	-9.41	-18.34
BASETP	-50	1.22	-0.61	4.81	0.81	1.65	1.38	1.17	1.22
BASETP	-10	0.16	-0.07	0.48	0.14	0.17	0.17	0.19	0.16
BASETP	10	-0.14	0.06	-0.36	-0.13	-0.13	-0.14	-0.18	-0.14
BASETP	50	-0.86	0.30	-1.45	-0.89	-0.61	-0.80	-1.19	-0.84
DEEPFR	-50	2.19	1.18	4.72	2.54	2.02	1.84	2.42	2.19
DEEPFR	-10	0.44	0.23	0.95	0.51	0.40	0.37	0.48	0.43
DEEPFR	10	-0.44	-0.23	-0.95	-0.51	-0.40	-0.37	-0.48	-0.43
DEEPFR	50	-4.32	-2.31	-9.57	-5.05	-3.93	-3.61	-4.78	-4.31
INFILT	-50	0.49	9.69	-20.15	1.13	1.36	0.10	-1.04	0.68
INFILT	-10	0.05	1.35	-3.13	0.19	0.19	-0.02	-0.28	0.07
INFILT	10	-0.03	-1.19	2.82	-0.17	-0.16	0.02	0.28	-0.05
INFILT	50	-0.05	-4.83	12.03	-0.71	-0.62	0.15	1.48	-0.11
INTFW	-50	-1.31	3.25	-1.52	-0.69	-1.68	-1.67	-1.34	-1.33
INTFW	-10	-0.19	0.41	-0.12	-0.10	-0.23	-0.27	-0.16	-0.19
INTFW	10	0.17	-0.36	0.06	0.09	0.20	0.24	0.13	0.17
INTFW	50	0.69	-1.37	0.05	0.37	0.84	1.02	0.49	0.70
LZSN	-50	1.96	3.06	-4.93	4.94	1.36	-2.21	4.94	2.03
LZSN	-10	0.34	0.49	-0.73	0.78	0.30	-0.31	0.77	0.35
LZSN	10	-0.34	-0.47	0.57	-0.72	-0.28	0.25	-0.79	-0.35
LZSN	50	-3.71	-4.44	2.43	-6.73	-2.93	0.92	-7.74	-3.78
CEPSC	-50	1.20	0.74	3.49	0.35	3.46	0.88	0.59	1.15
CEPSC	-10	0.21	0.15	0.45	0.08	0.63	0.17	0.01	0.21
CEPSC	10	-0.21	-0.14	-0.47	-0.09	-0.60	-0.18	-0.01	-0.21
CEPSC	50	-0.98	-0.62	-2.58	-0.31	-2.74	-0.80	-0.42	-0.96
LZETP	-50	7.13	7.92	1.99	6.29	4.22	8.62	9.49	7.14
LZETP	-10	1.52	1.51	1.37	1.21	0.87	1.99	1.99	1.51
LZETP	10	-1.62	-1.56	-1.83	-1.23	-0.93	-2.21	-2.11	-1.62
LZETP	50	-6.54	-6.08	-8.44	-4.97	-3.86	-8.76	-8.55	-6.50
KVARY	-50	-0.51	-1.43	12.54	-0.36	-0.19	-0.82	-0.61	-0.93
KVARY	-10	-0.09	-0.26	2.17	-0.05	-0.06	-0.12	-0.15	-0.16
KVARY	10	0.09	0.25	-2.08	0.04	0.06	0.12	0.15	0.15
KVARY	50	0.40	1.19	-9.43	0.16	0.36	0.50	0.73	0.68
UZSN	-50	9.13	13.40	-1.67	2.82	17.77	10.16	8.25	9.22
UZSN	-10	1.40	2.07	-0.26	0.52	2.48	1.73	1.10	1.42
UZSN	10	-1.21	-1.77	0.20	-0.49	-1.85	-1.60	-1.00	-1.22
UZSN	50	-5.05	-7.57	1.10	-1.97	-7.59	-6.95	-4.08	-5.11

[1]Actual parameter value used

Water Quality Parameter Sensitivity Analysis

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1997 through 2002, and model parameters established for 2012 conditions. The three HSPF parameters impacting the model's water quality response (**Table B. 8**) were increased and decreased by amounts that were consistent with the range of values for the parameter. Bacteria concentration in interflow had the maximum impact on monthly geometric mean which is a result of the relatively high base value of this concentration. Maximum fecal coliform accumulation on land surfaces (MON-SQOLIM) has a considerable impact on monthly geometric means followed by the First Order Decay (FSTDEC) and wash-off rate (WSQOP) (**Table B. 9**). Graphical depictions of the results of this sensitivity analysis can be seen in **Figure B. 11** through **Figure B. 14**.

Table B. 8 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0 – 5.9E+10
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	1.0
FSTDEC	In-stream First Order Decay Rate	1/day	2.0
IOQC	Fecal coliform concentration in interflow	cfu/ft^3	10,000

Table B. 9 Percent change in average monthly *E. coli* mean for the years 1997-2002.

Model Parameter	Parameter Change (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
		Percent Change in Average Monthly *E. coli* Geometric Mean for 1997-2002											
FSTDEC	-50	2.69	3.10	2.69	2.60	1.94	1.84	1.60	1.64	2.56	1.89	1.81	2.31
FSTDEC	-10	0.53	0.60	0.53	0.51	0.38	0.36	0.31	0.32	0.49	0.36	0.36	0.45
FSTDEC	10	-0.52	-0.59	-0.52	-0.51	-0.38	-0.36	-0.31	-0.32	-0.49	-0.35	-0.35	-0.45
FSTDEC	50	-2.57	-2.89	-2.58	-2.49	-1.86	-1.74	-1.53	-1.56	-2.37	-1.68	-1.73	-2.21
SQOLIM	-50	-13.23	-9.60	-8.76	-8.27	-6.99	-6.30	-5.95	-5.37	-9.76	-7.41	-13.23	-9.53
SQOLIM	-25	-5.56	-3.84	-3.52	-3.25	-2.86	-2.54	-2.36	-2.10	-4.00	-3.03	-5.76	-3.92
SQOLIM	25	3.50	2.27	2.04	1.80	1.62	1.45	1.35	1.20	2.40	1.81	3.68	2.38
SQOLIM	50	3.70	2.42	2.18	1.95	1.71	1.62	1.47	1.31	2.61	1.85	3.79	2.48
WSQOP	-50	2.77	1.78	1.82	1.41	0.77	0.50	0.60	0.79	0.87	0.25	1.36	1.52
WSQOP	-10	0.34	0.22	0.22	0.18	0.09	0.07	0.08	0.10	0.12	0.03	0.15	0.18
WSQOP	10	-0.28	-0.18	-0.19	-0.15	-0.08	-0.06	-0.07	-0.08	-0.10	-0.02	-0.12	-0.14
WSQOP	50	-1.06	-0.70	-0.70	-0.56	-0.28	-0.26	-0.26	-0.33	-0.43	-0.09	-0.46	-0.54
IOQC	-100	-38.91	-47.24	-48.97	-46.59	-34.62	-35.60	-34.14	-31.65	-39.25	-13.24	-14.71	-27.95
IOQC	-50	-19.19	-23.27	-24.10	-22.96	-17.13	-17.58	-16.84	-15.58	-19.36	-6.58	-7.32	-13.83
IOQC	50	18.82	22.77	23.58	22.48	16.85	17.27	16.52	15.26	18.97	6.52	7.25	13.62
IOQC	100	37.34	45.17	46.75	44.60	33.46	34.28	32.80	30.28	37.65	12.98	14.45	27.07

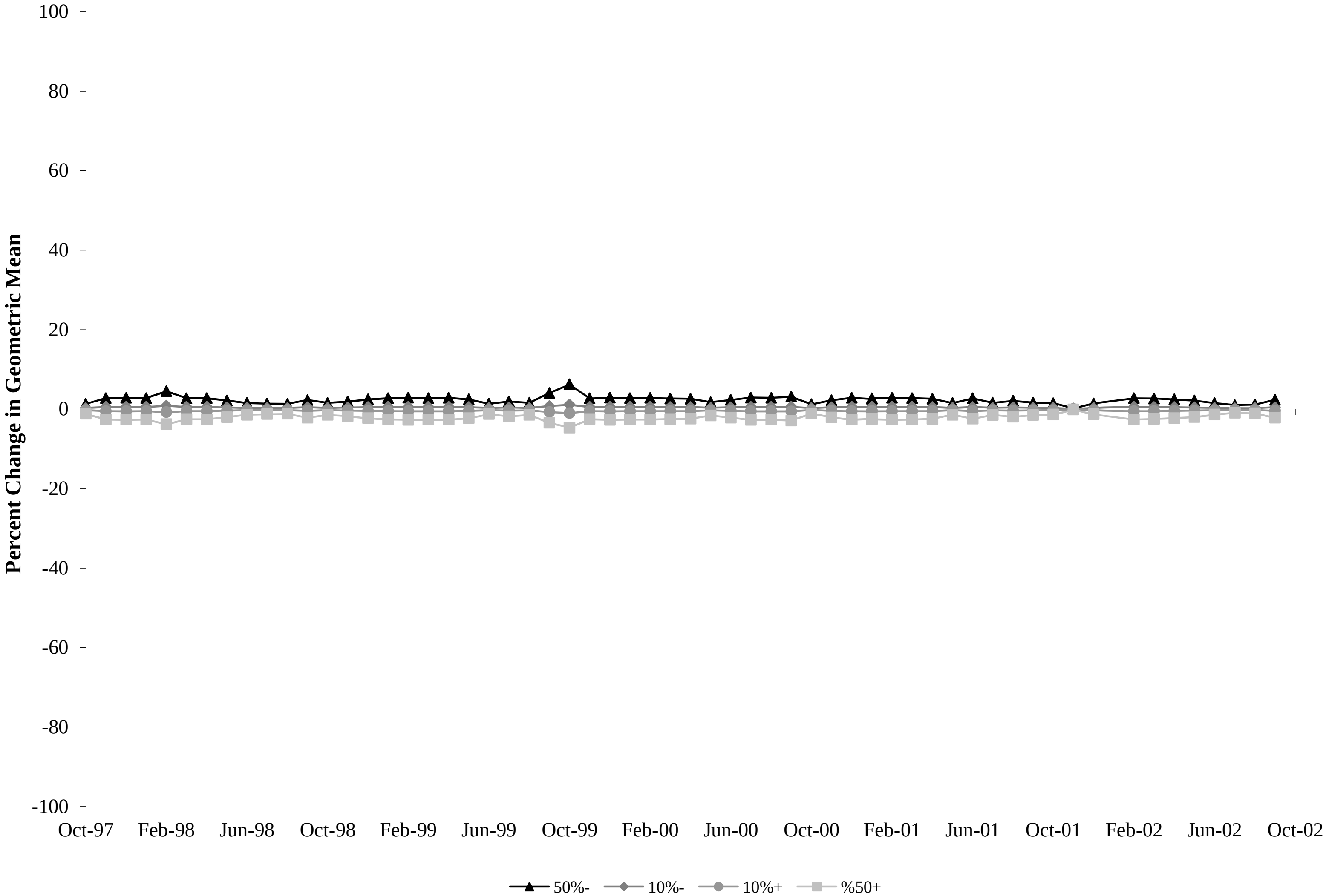

Figure B. 11 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the in-stream first-order decay rate (FSTDEC).

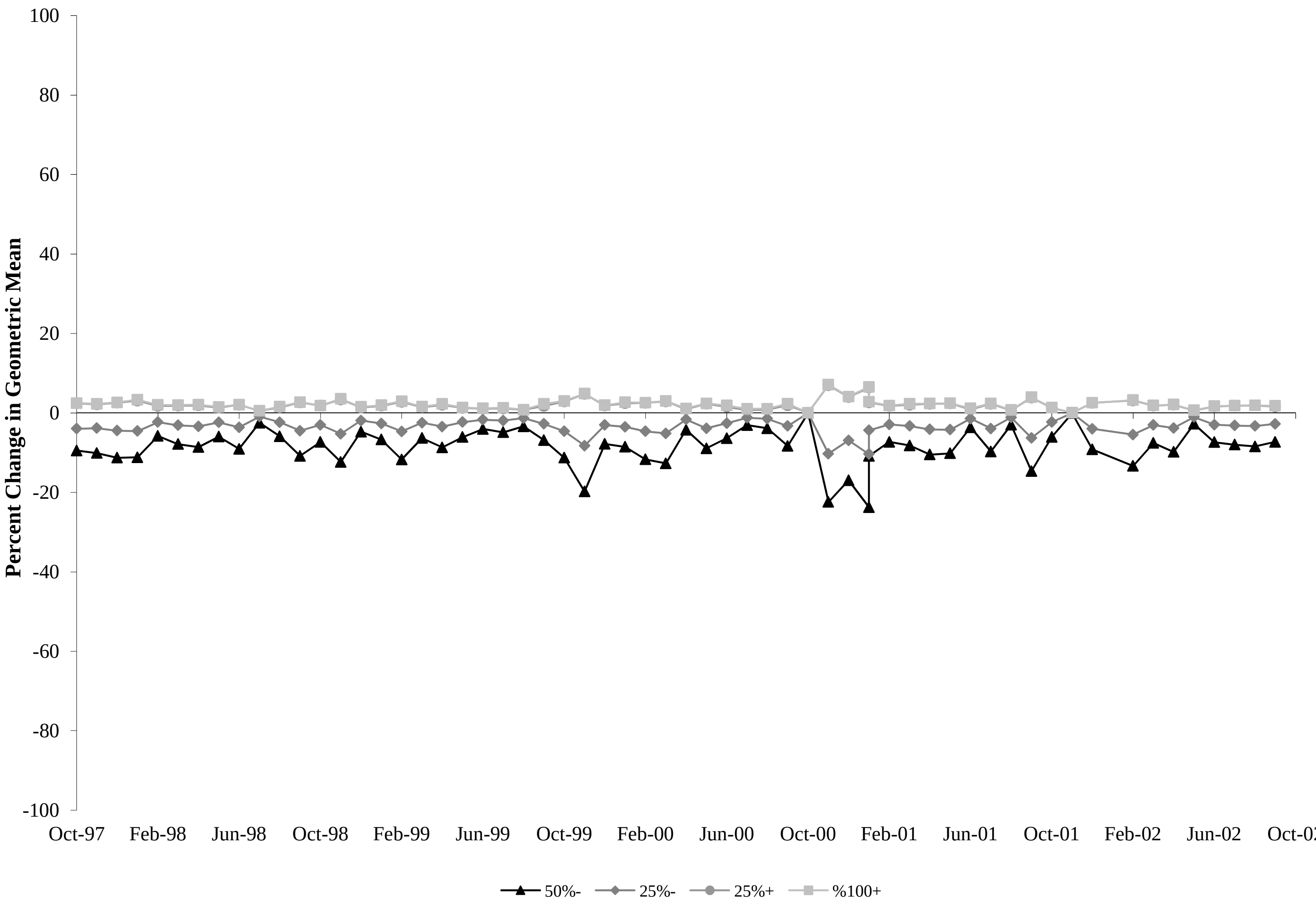

Figure B. 12 Results of sensitivity analysis on monthly mean concentrations as affected by changes in maximum fecal accumulation on land (MON-SQOLIM).

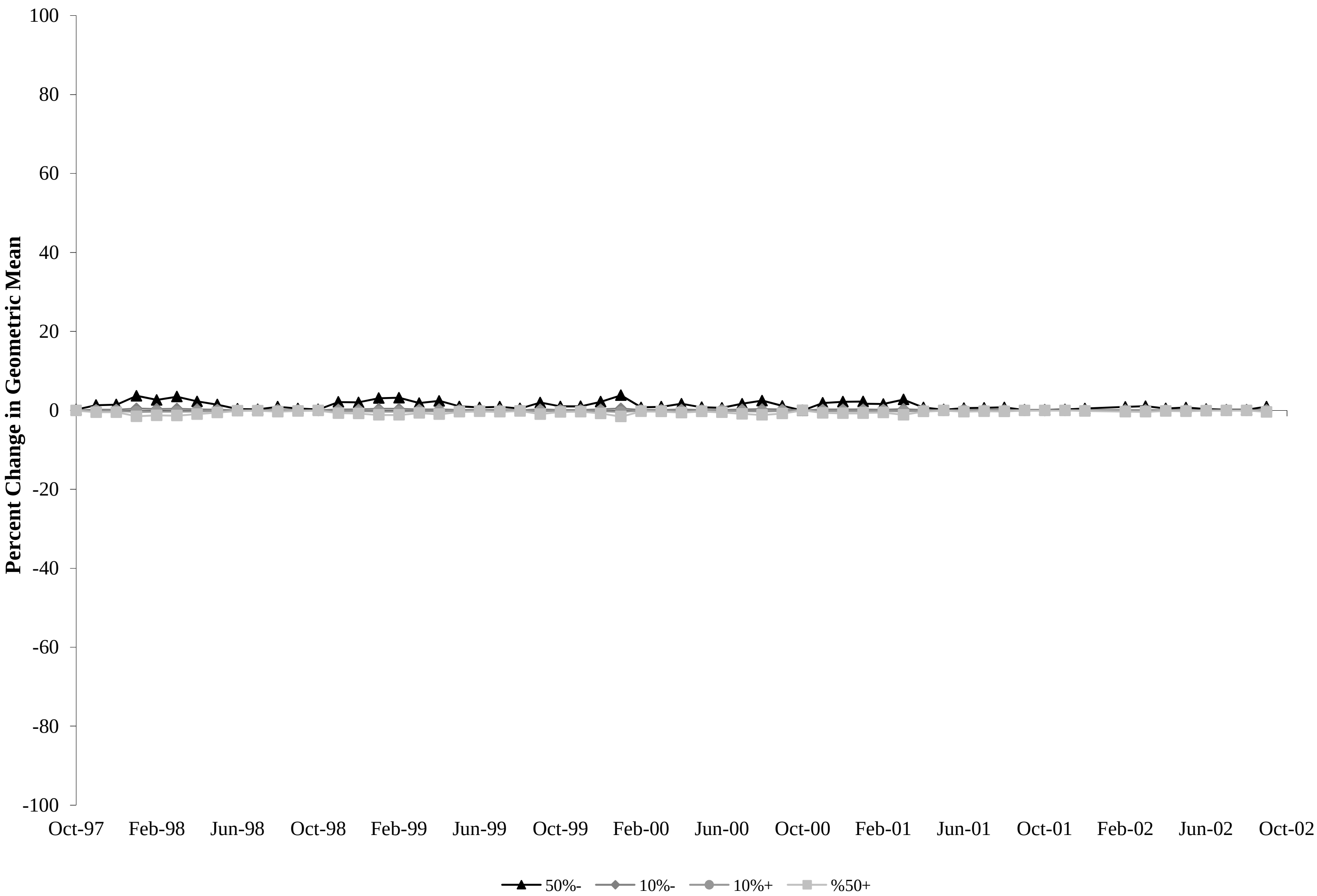

Figure B. 13 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the wash-off rate from land surfaces (WSQOP).

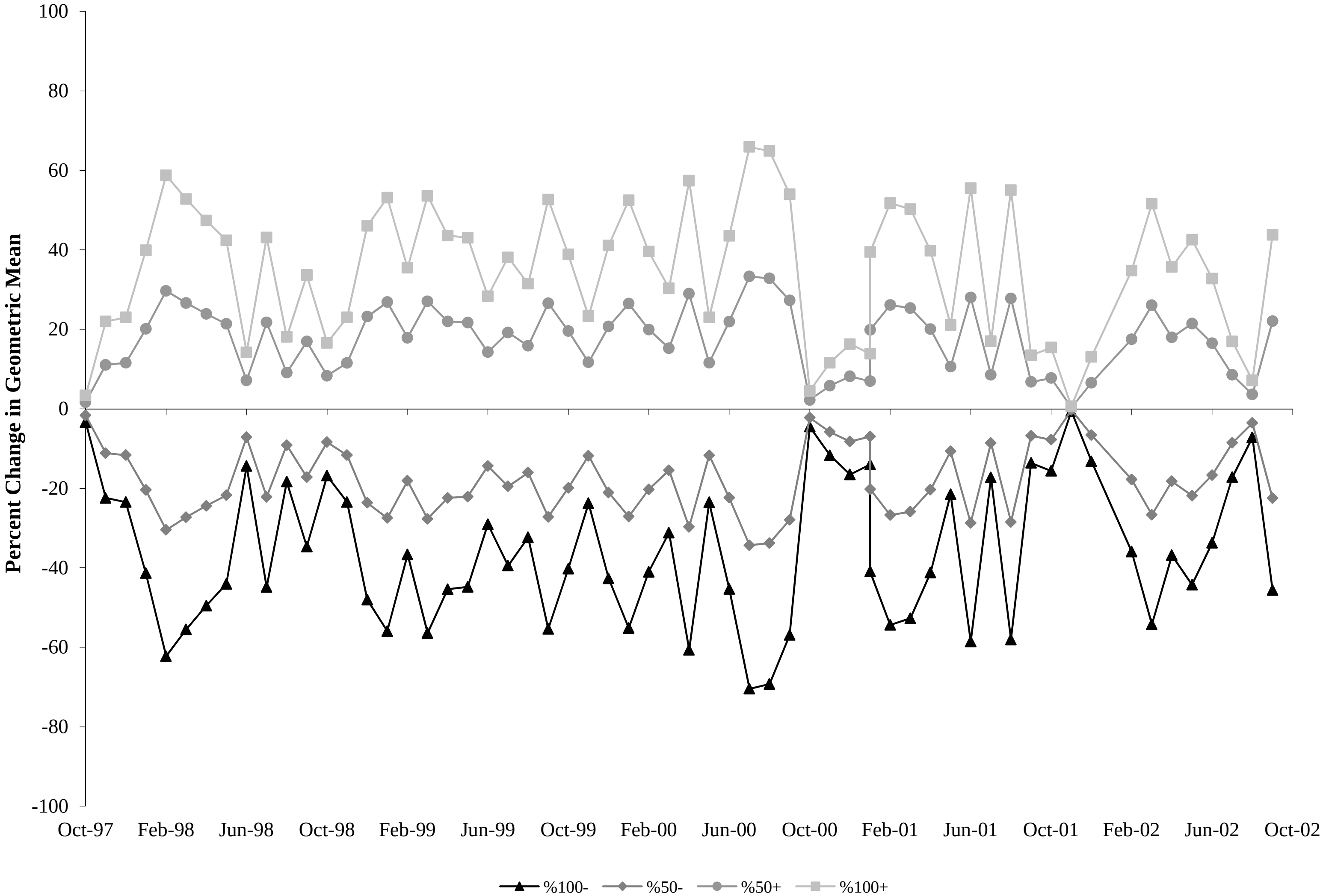

Figure B. 14 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the bacteria concentration in interflow (IOQC).

In addition to analyzing the sensitivity of the model response to changes in water quality transport and die-off parameters, the response of the model to changes in land-based and direct loads was also analyzed. It is evident in **Figure B. 15** that the model predicts a linear relationship between increased fecal coliform concentrations in both land and direct applications, and total load reaching the stream. The magnitude of this relationship differs between land applied and direct loadings; a 100% increase in the land applied loads results in an increase of about 80% in stream loads, while a 100% increase in direct loads results in approximately a 10% increase in stream loads. Both direct loads and land applied loads have a significant impact on the geometric mean concentrations (**Figure B. 16** and **Figure B. 17**).

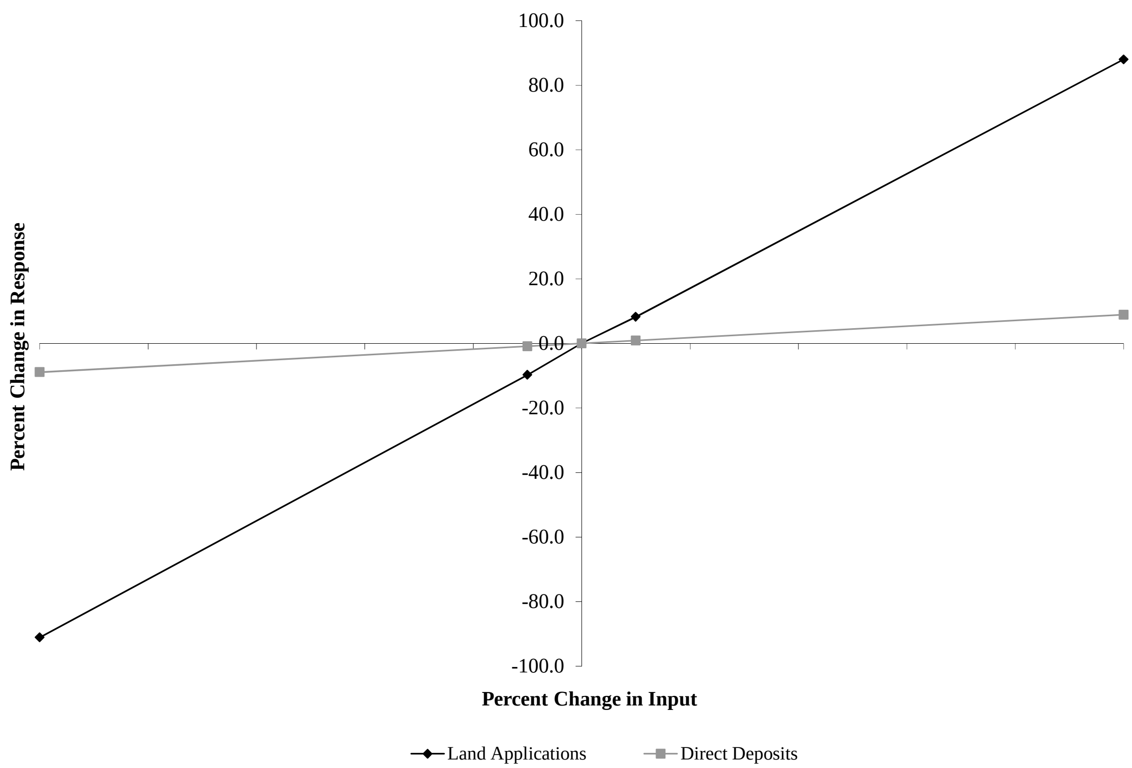

Figure B. 15 Results of total loading sensitivity analysis for outlet of the study area.

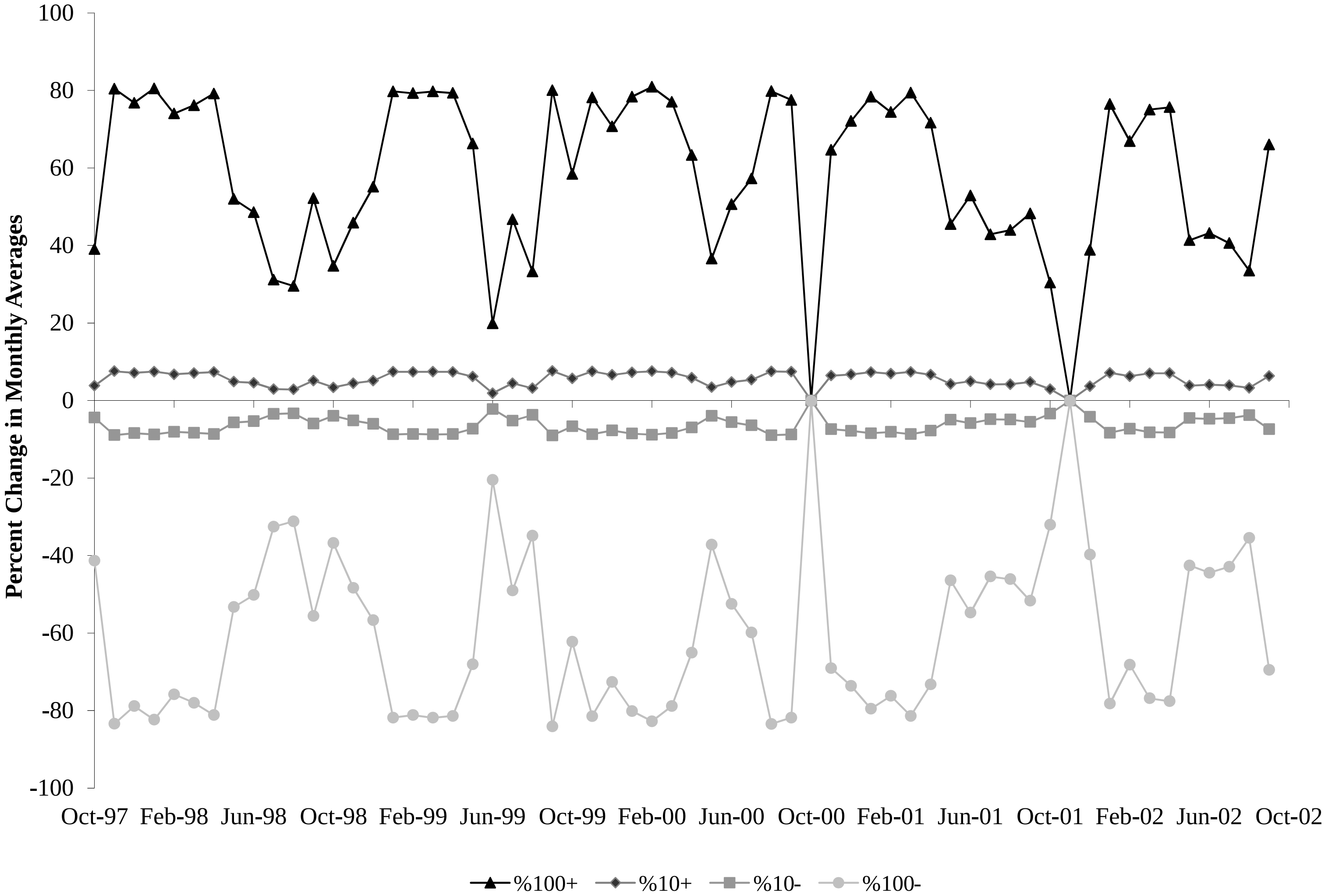

Figure B. 16 Results of sensitivity analysis on monthly geometric-mean concentrations in the study area, as affected by changes in land-based loadings.

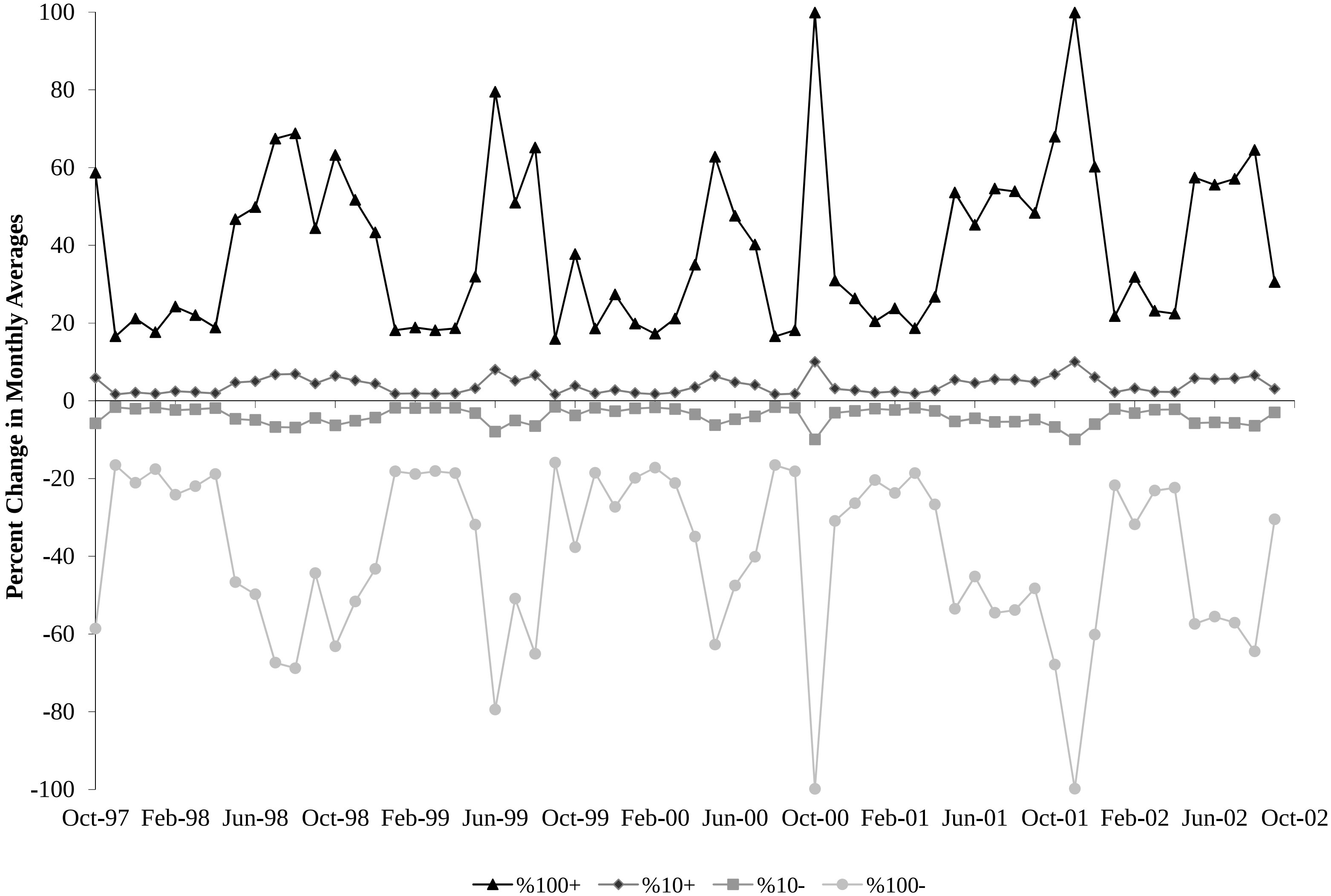

Figure B. 17 Results of sensitivity analysis on monthly geometric-mean concentrations in the study area, as affected by changes in loadings from direct nonpoint sources.

Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Through calibration, these parameters are adjusted within appropriate ranges until the model performance is deemed acceptable. Water quality calibration involves comparing historical DEQ monitored data collected within the study area to simulated water quality concentrations obtained by running the computer model. The computer model used in the analysis is capable of generating a simulated output at any needed location within the watershed by placing a subwatershed outlet at that location within the model. This ability allows for the calibration process to honor spatial variability within the larger study area.

HSPF - Hydrologic Calibration and Validation

Paired-watershed approach was utilized in calibrating hydrologic parameters within the study area. Initial parameters were estimated from available spatial data and then adjusted based on rate of change in these parameters that was estimated for the nearby, hydrologically calibrated Nansemond River watershed.

HSPF – Bacteria Water Quality Calibration

Water quality calibration is complicated by a number of factors; first, water quality (*E. coli* and *enterococci*) concentrations are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters. Second, the concentration of *E. coli* is particularly variable. Variability in location and timing of fecal deposition, variability in the density of bacteria in feces (among species and for an individual animal), environmental impacts on re-growth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling *E. coli* and *enterococci* concentrations. Additionally, the VADEQ data were censored at specific high and low values. Limited amount of measured data for use in calibration and the practice of censoring both high and low concentrations impede the calibration process.

Three parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), monthly maximum accumulation on land (MON-SQOLIM), and the rate of surface runoff that will remove 90% of stored fecal bacteria per hour (WSQOP). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled bacteria concentrations was established. Observed *E. coli* and *fecal coliform (*as a surrogate for *enterococci)* monitored data were used in the calibration process. **Table B. 10** shows the model parameters utilized in calibration with their typical ranges, initial estimates, and final calibrated values. Bacteria calibration was conducted for the period of October 2004 to September 2009. Simulation period varies by station.

Table B. 10 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0 – 1.1E+11	0.0 – 5.9E+10
WSQOP	in/hr	0.05 – 3.00	0.0 – 2.80	0.0 – 2.8
FSTDEC	1/day	0.01 – 10.00	1.0	0.1 - 5.0

Figure B. 18 through **Figure B. 25** show the results of water quality calibration. Monitored values are an instantaneous snapshot of the bacteria level, whereas the modeled values are daily averages based on hourly modeling. The hourly bacteria concentrations as predicted by the model have a rage wider than the average daily and encompass the high and low observed data points. The modeled data follows the trend of monitored data.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. **Table B. 11** shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the simulated and observed results at the calibration locations.

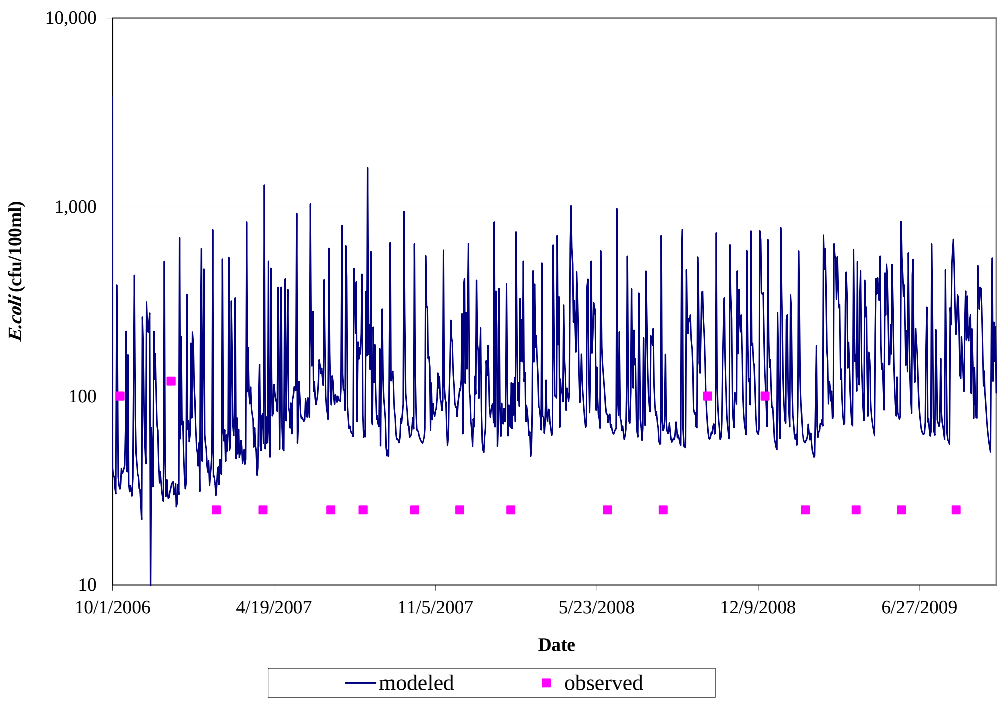

Figure B. 18 *E. coli* calibration for 10/1/2006 to 9/30/2009 for VADEQ station 5BNLR013.61 in subwatershed 3 on North Landing River.

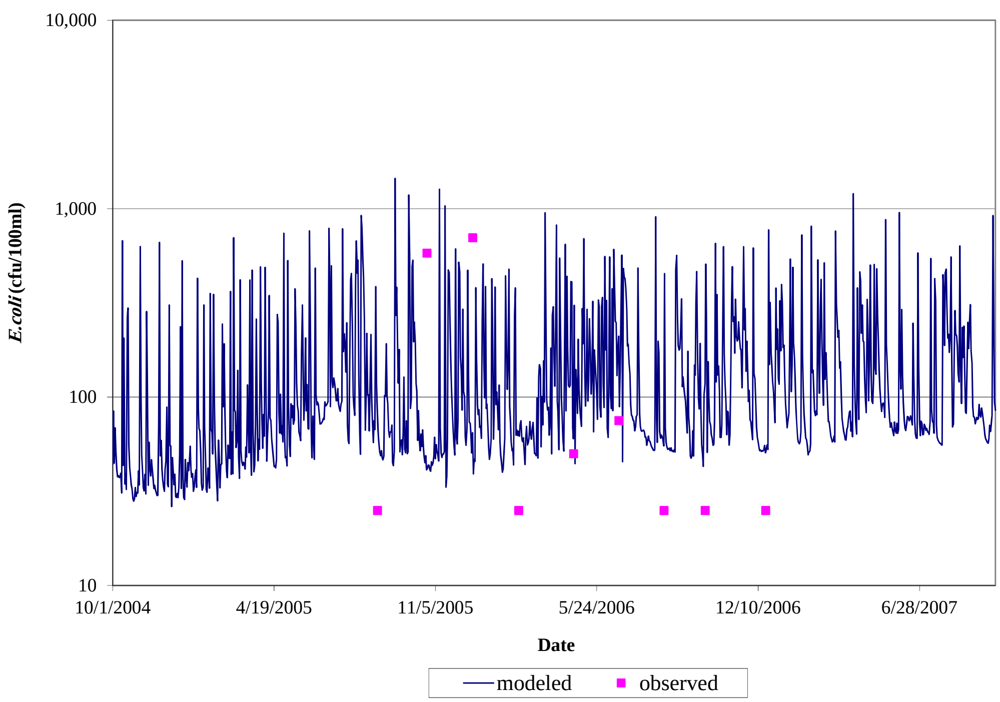

Figure B. 19 *E. coli* calibration for 10/1/2004 to 9/30/2007 for VADEQ station 5BNLR010.75 in subwatershed 1 on North landing River.

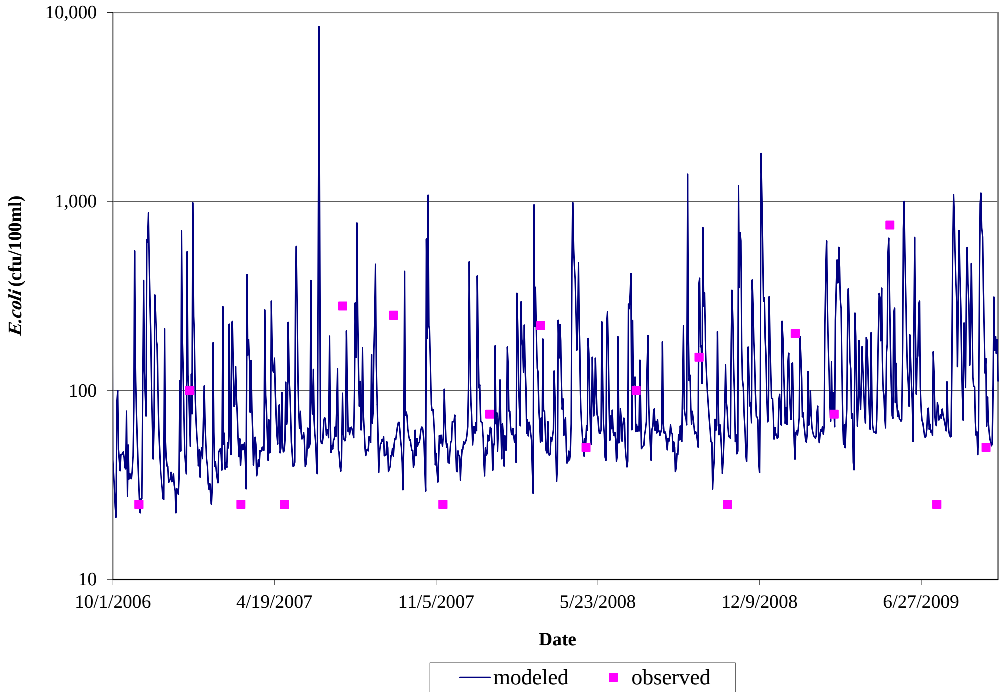

Figure B. 20 ***E. coli*** **calibration for 10/1/2006 to 9/30/2009 for VADEQ station 5BPCT001.79 in subwatershed 4 on Pocaty River.**

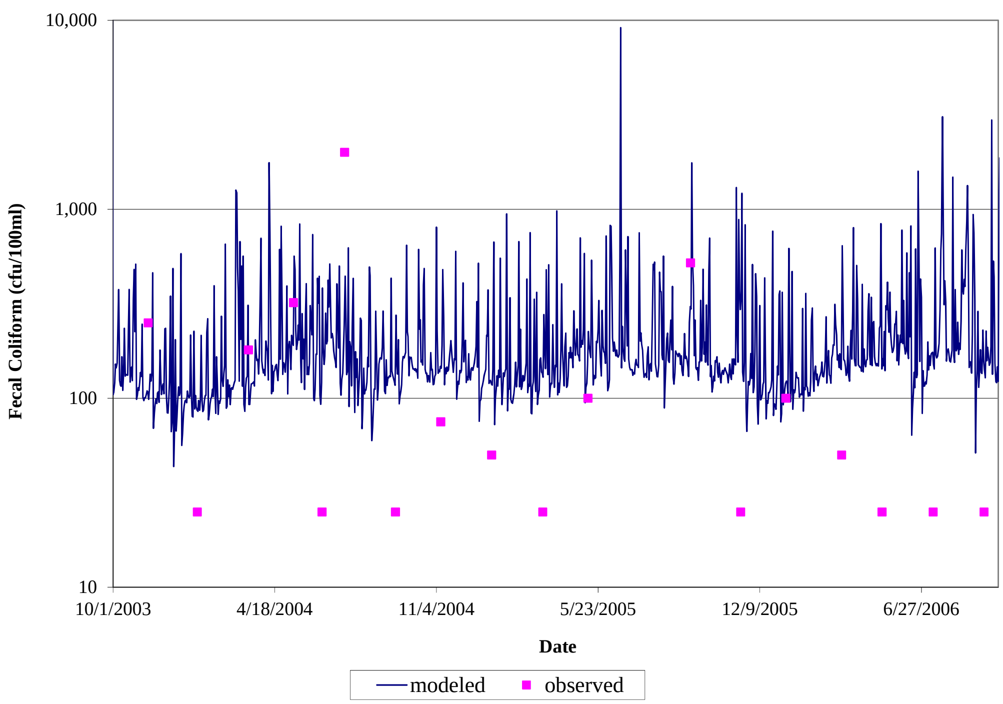

Figure B. 21 Fecal coliform calibration for 10/1/2003 to 9/30/2006 for VADEQ station 5BASH002.20 in subwatershed 8 on Ashville Bridge Creek.

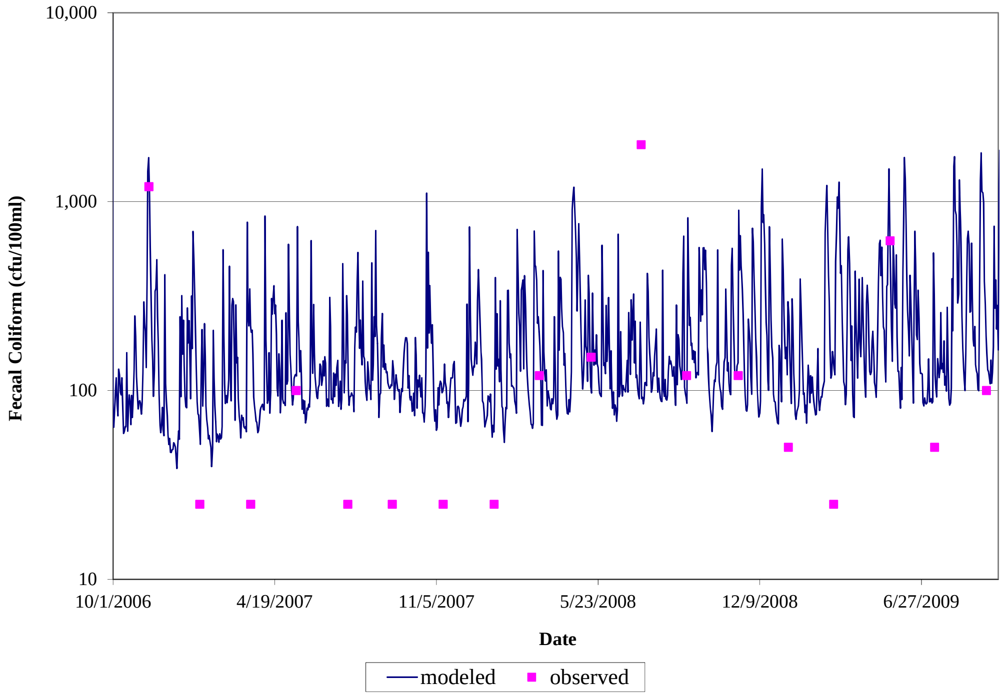

Figure B. 22 Fecal coliform calibration for 10/1/2006 to 9/30/2009 for VADEQ station 5BMDY000.00 in subwatershed 5 on Muddy Creek.

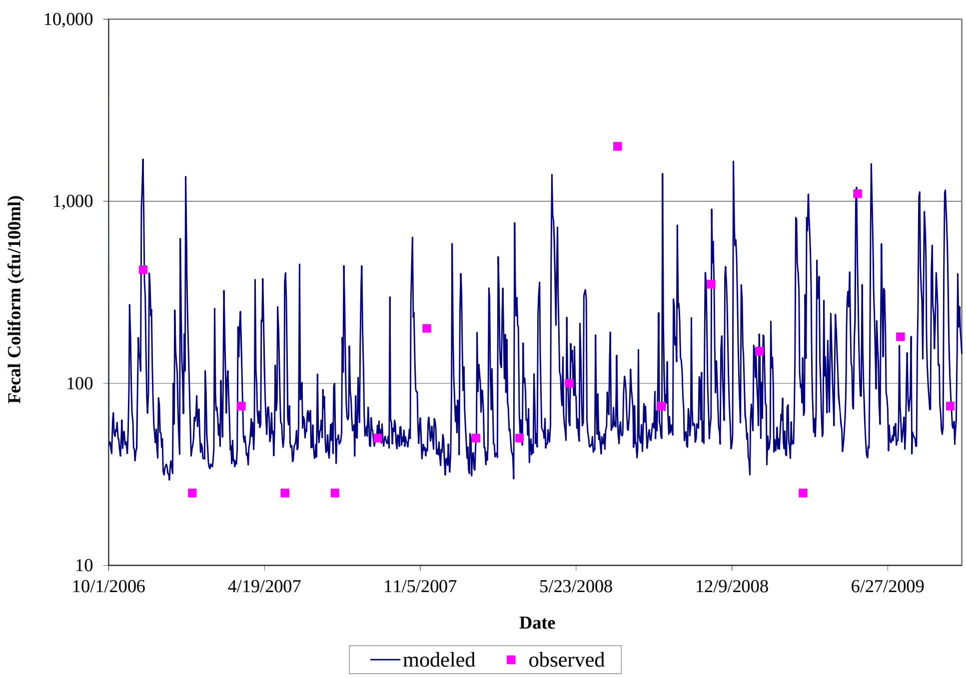

Figure B. 23 Fecal coliform calibration for 10/1/2006 to 9/30/2009 for VADEQ station 5BBBC000.76 in subwatershed 6 on Beggars Bridge Creek.

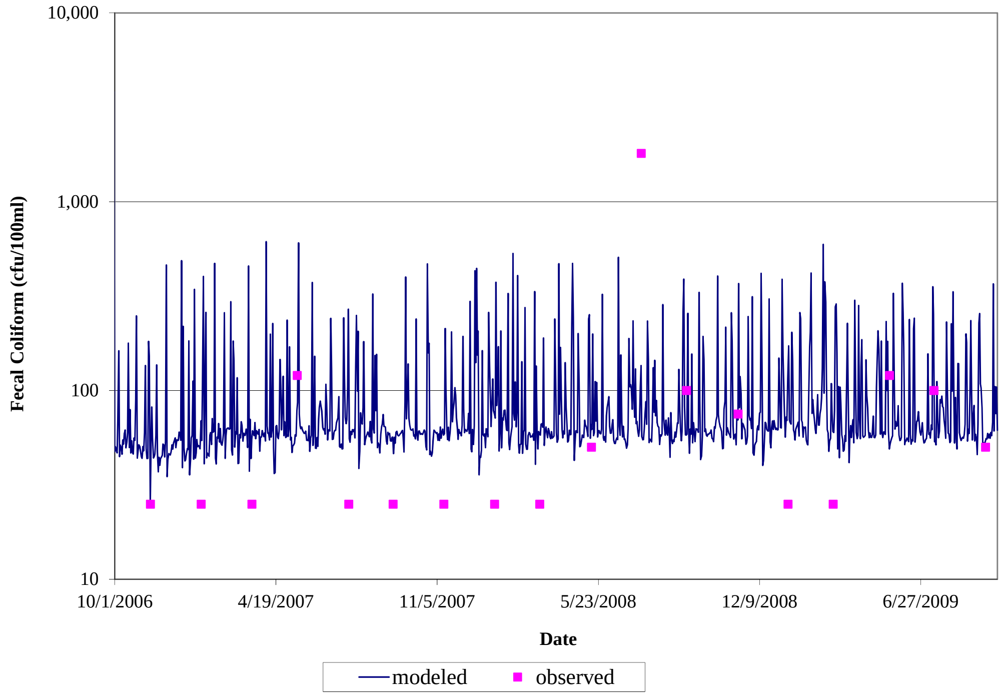

Figure B. 24 Fecal coliform calibration for 10/1/2006 to 9/30/2009 for VADEQ station 5BHPC001.46 in subwatershed 10 on Hell Point Creek.

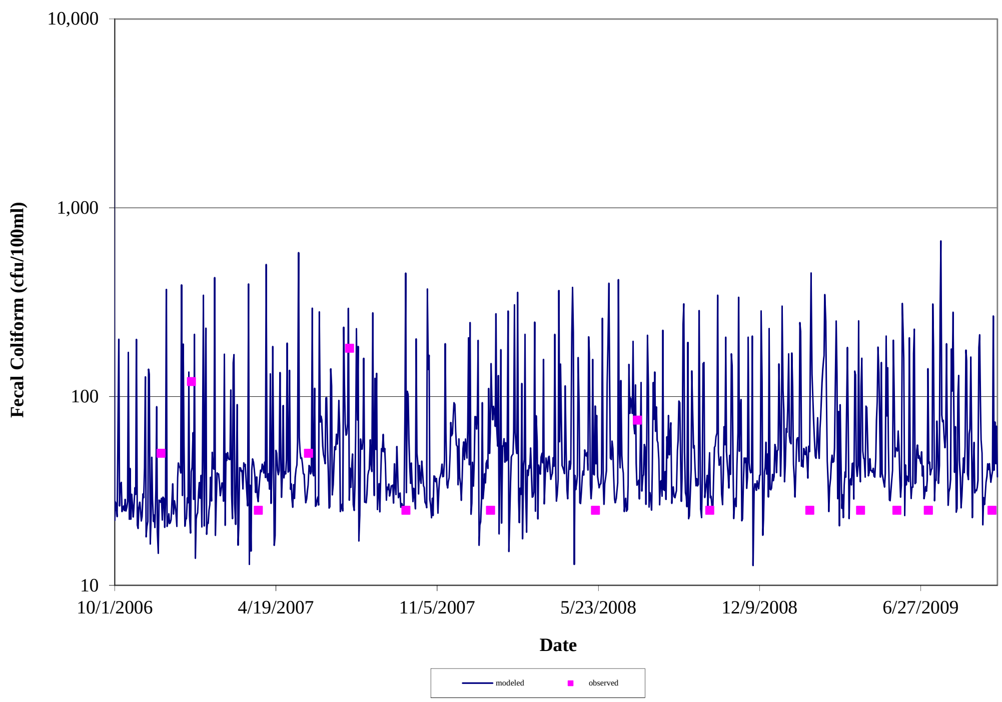

Figure B. 25 Fecal coliform calibration for 10/1/2006 to 9/30/2009 for VADEQ station 5BHPC000.00 in subwatershed 9 on Hell Point Creek.

Table B. 11 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the calibration period.

Station	Parameter	Sub-watershed	Maximum Value (cfu/100 mL)		SS % violations [1]		Geometric Mean (cfu/100 mL)	
			Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
5BNLR013.61	E.coli	3	120.00	1,616.73	0.00%	18.70%	35.02	113.06
5BNLR010.75	E.coli	1	700.00	1,448.11	22.22%	16.97%	62.65	100.09
5BPCT001.79	E.coli	4	750.00	8,425.21	16.67%	11.22%	78.18	85.11
5BASH002.20	Fecal coliform	8	2,000.00	9,143.85	15.79%	10.58%	84.49	173.15
5BMDY000.00	Fecal coliform	5	2,000.00	1,810.92	16.67%	11.59%	85.44	151.08
5BBBC000.76	Fecal coliform	6	2,000.00	3,320.49	16.67%	13.41%	107.37	130.51
5BHPC001.46	Fecal coliform	10	1,800.00	1,095.62	5.56%	5.84%	50.54	109.22
5BHPC000.00	Fecal coliform	9	180.00	1,199.49	0.00%	3.83%	37.36	70.11

[1] SS = single sample instantaneous standard violations >235 cfu/100 mL for *E. coli* and >400 cfu/100 mL for fecal coliform.

HSPF – Bacteria Water Quality Validation

Bacteria water quality model validation was performed for the period of October 2003 to September 2006. **Figure B. 26** through **Figure B. 31** show the results of water quality validation. **Table B. 12** shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations.

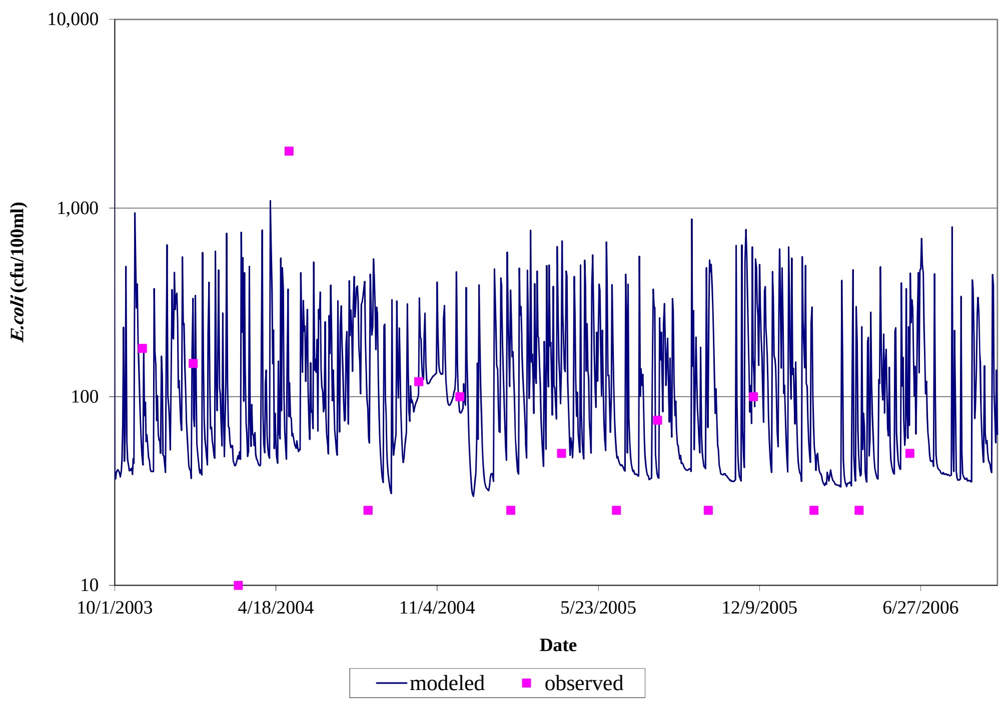

Figure B. 26 *E. coli* validation for 10/1/2003 to 9/30/2006 for VADEQ station 5BNLR013.61 in subwatershed 3 on North Landing River.

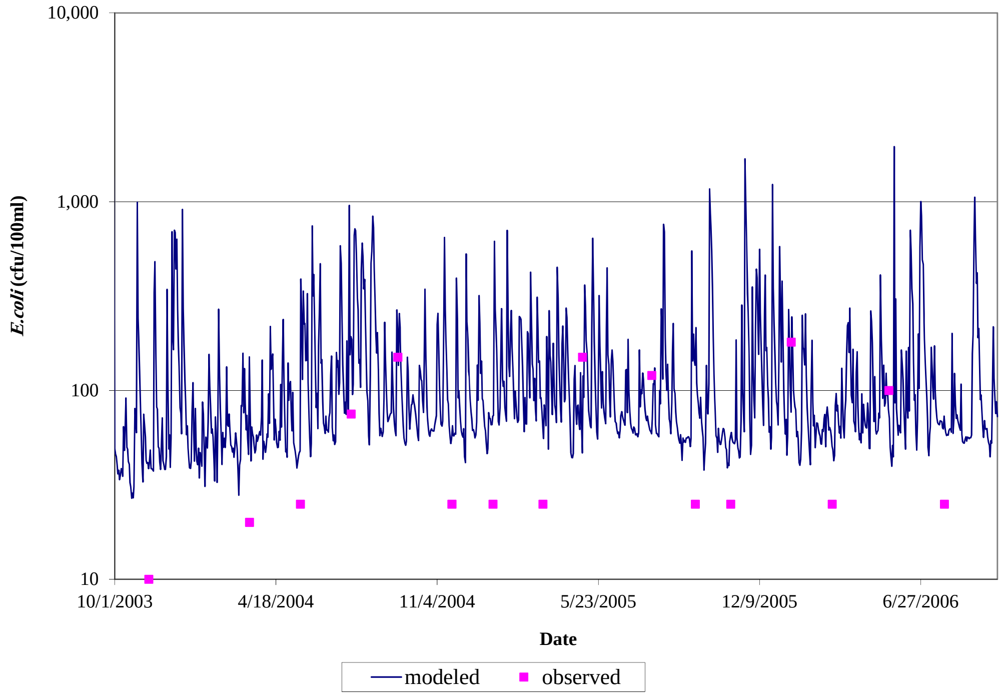

Figure B. 27 *E. coli* validation for 10/1/2003 to 9/30/2006 for VADEQ station 5BPCT001.79 in subwatershed 4 on Pocaty River.

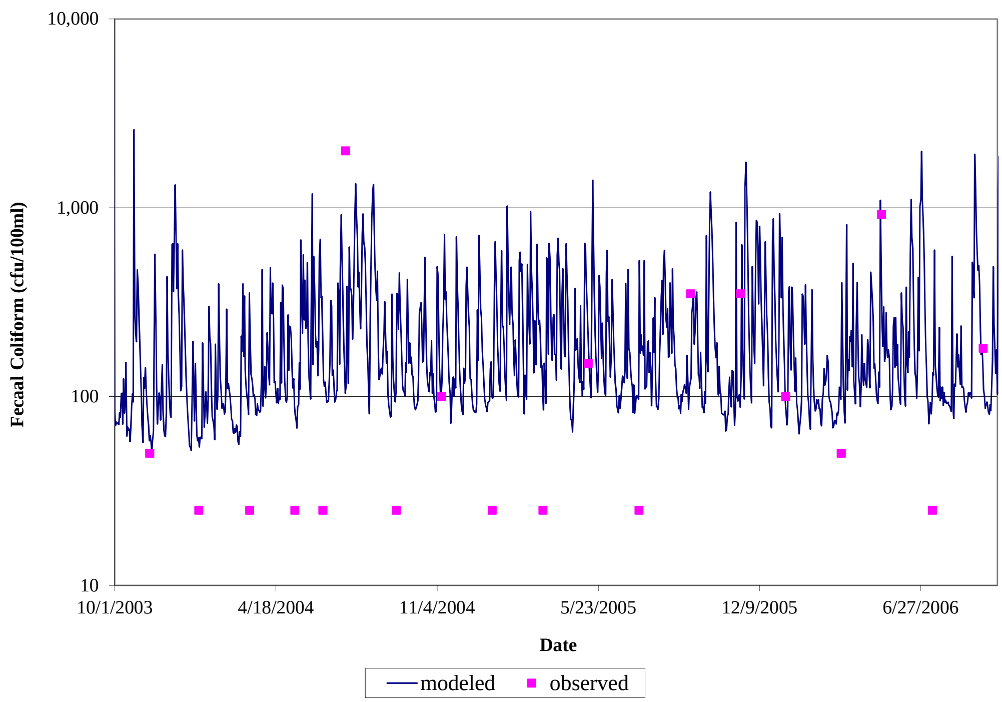

Figure B. 28 Fecal coliform validation for 10/1/2003 to 9/30/2006 for VADEQ station 5BMDY000.00 in subwatershed 5 on Muddy Creek.

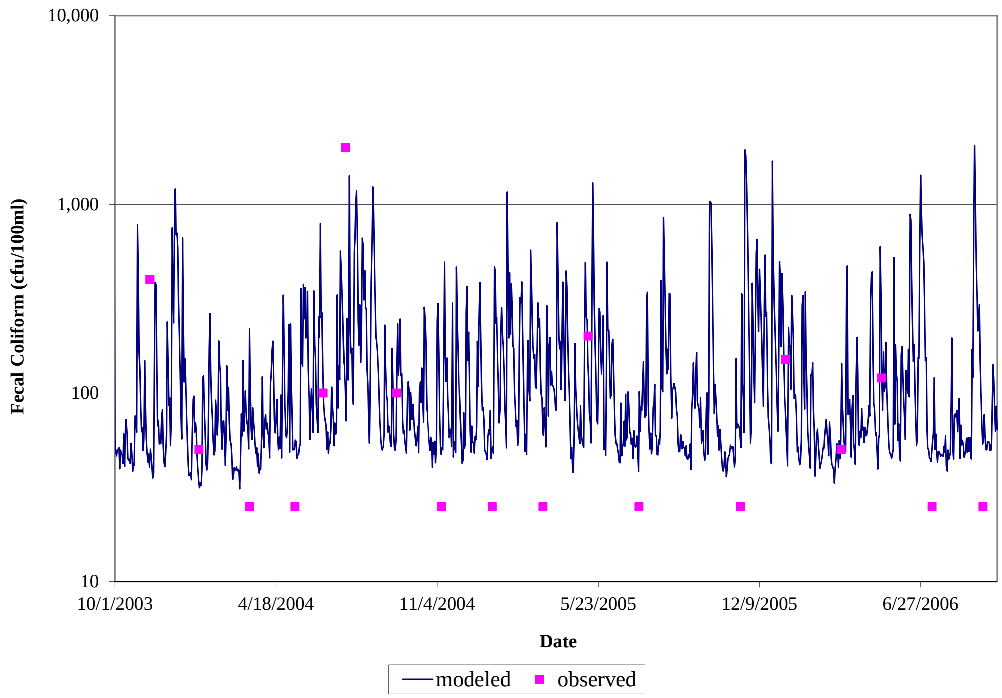

Figure B. 29 Fecal coliform validation for 10/1/2003 to 9/30/2006 for VADEQ station 5BBBC000.76 in subwatershed 6 on Beggars Bridge Creek.

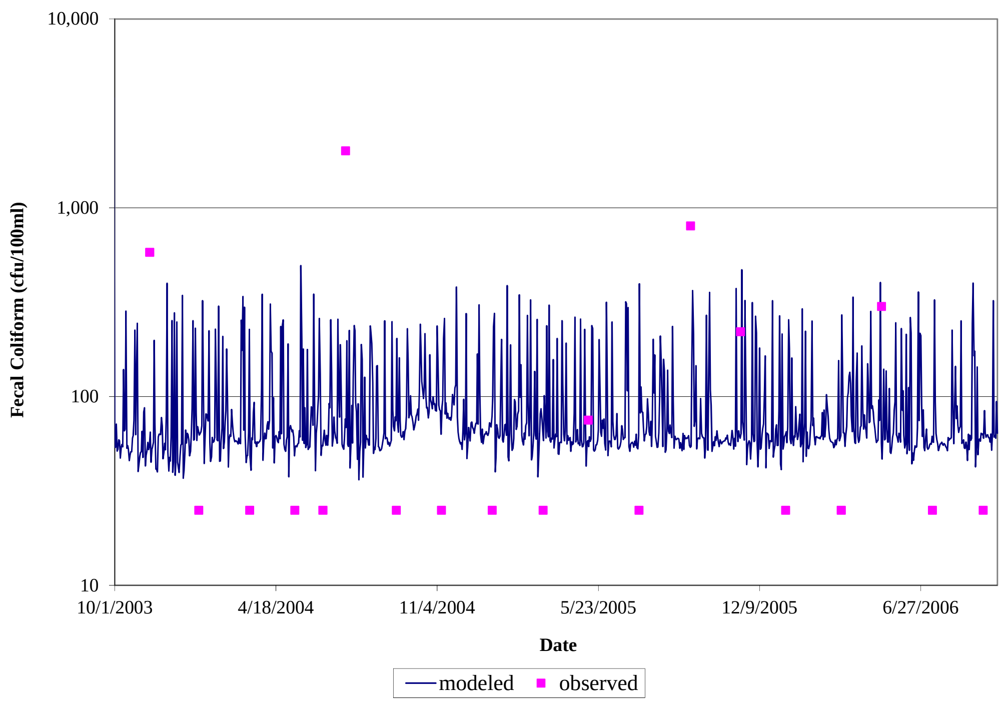

Figure B. 30 Fecal coliform validation for 10/1/2003 to 9/30/2006 for VADEQ station 5BHPC001.46 in subwatershed 10 on Hell Point Creek.

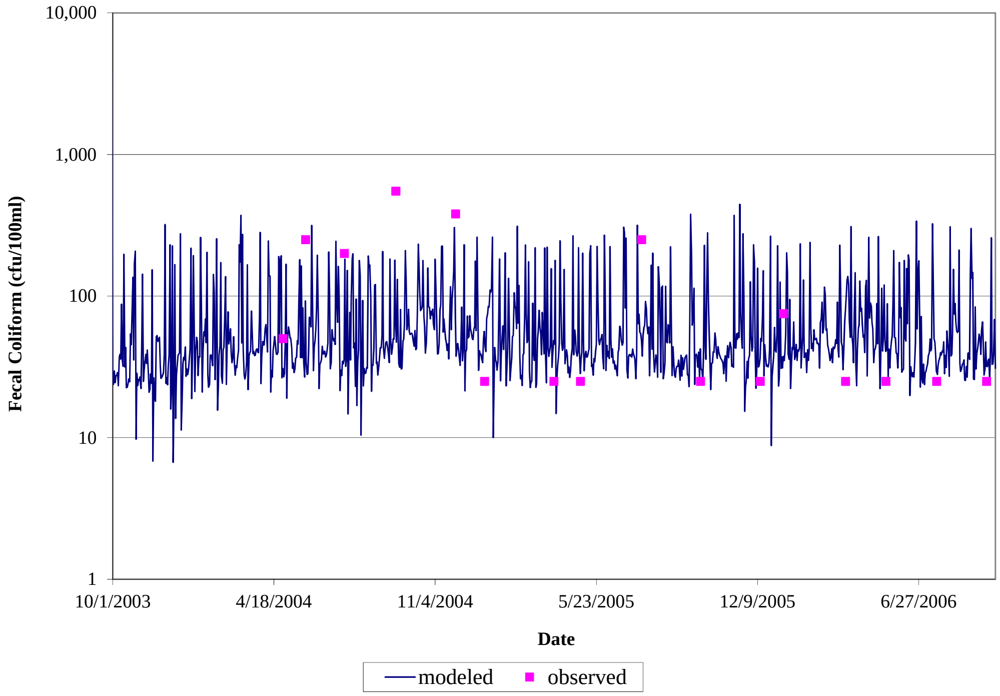

Figure B. 31 Fecal coliform calibration for 10/1/2006 to 9/30/2009 for VADEQ station 5BHPC000.00 in subwatershed 9 on Hell Point Creek.

Table B. 12 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the validation period.

Station	Parameter	Sub-watershed	Maximum Value (cfu/100 mL)		SS % violations [1]		Geometric Mean (cfu/100 mL)	
			Monitored	**Simulated**	**Monitored**	**Simulated**	**Monitored**	**Simulated**
5BNLR013.61	E.coli	3	2,000.00	1,093.07	6.25%	18.61%	60.19	97.02
5BPCT001.79	E.coli	4	180.00	1,958.52	0.00%	11.68%	42.45	94.41
5BMDY000.00	Fecal coliform	5	2,000.00	2,590.97	10.53%	13.96%	76.26	168.03
5BBBC000.76	Fecal coliform	6	2,000.00	4,052.85	11.11%	14.60%	63.41	148.06
5BHPC001.46	Fecal coliform	10	2,000.00	864.43	21.05%	6.20%	60.37	112.84
5BHPC000.00	Fecal coliform	9	550.00	770.19	6.25%	3.19%	61.06	73.04

[1] SS = single sample instantaneous standard violations >235 cfu/100 mL for E. coli and >400 cfu/100 mL for fecal coliform.

APPENDIX C

Current Conditions for Fecal Coliform Loads

Table C. 1 Current conditions of land applied fecal coliform load of North Landing River (subs 1, 2, and 3):

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Residential	16.2E13	14.6E13	16.2E13	15.6E13	16.1E13	15.6E13	16.1E13	16.1E13	15.6E13	16.1E13	15.6E13	16.2E13	19.0E14
Cropland	80.1E11	72.3E11	80.1E11	77.5E11	80.1E11	77.5E11	80.1E11	80.1E11	77.5E11	80.1E11	77.5E11	80.1E11	94.3E12
Forest	55.2E11	49.8E11	55.2E11	53.4E11	55.2E11	53.4E11	55.2E11	55.2E11	53.4E11	55.2E11	53.4E11	55.2E11	64.9E12
Pasture/Hay	41.8E12	37.8E12	41.5E12	39.7E12	41.0E12	39.3E12	40.6E12	40.6E12	39.7E12	41.5E12	40.1E12	41.8E12	48.5E13
Commercial	30.2E10	27.3E10	30.2E10	29.3E10	30.2E10	29.3E10	30.2E10	30.2E10	29.3E10	30.2E10	29.3E10	30.2E10	35.6E11
LAX	11.6E11	10.4E11	15.0E11	18.7E11	19.3E11	22.0E11	22.7E11	22.7E11	18.7E11	15.0E11	14.5E11	11.6E11	20.2E12
Open Space	11.4E12	10.3E12	11.4E12	11.1E12	11.4E12	11.1E12	11.4E12	11.4E12	11.1E12	11.4E12	11.1E12	11.4E12	13.5E13
Wetland	22.0E12	19.9E12	22.0E12	21.3E12	22.0E12	21.3E12	22.0E12	22.0E12	21.3E12	22.0E12	21.3E12	22.0E12	26.0E13
Barren	16.6E10	15.0E10	16.6E10	16.1E10	16.6E10	16.1E10	16.6E10	16.6E10	16.1E10	16.6E10	16.1E10	16.6E10	19.6E11

Table C. 2 Current conditions of land applied fecal coliform load of Pocaty River (sub 4):

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Residential	60.6E11	54.4E11	59.6E11	57.3E11	58.9E11	56.6E11	57.8E11	57.8E11	56.0E11	57.5E11	56.0E11	59.2E11	69.2E12
Barren	65.5E09	59.2E09	65.5E09	63.4E09	65.5E09	63.4E09	65.5E09	65.5E09	63.4E09	65.5E09	63.4E09	65.5E09	77.2E10
Cropland	16.7E12	15.0E12	16.7E12	16.1E12	16.7E12	16.1E12	16.7E12	16.7E12	16.1E12	16.7E12	16.1E12	16.7E12	19.6E13
Forest	28.8E11	26.0E11	28.8E11	27.9E11	28.8E11	27.9E11	28.8E11	28.8E11	27.9E11	28.8E11	27.9E11	28.8E11	33.9E12
Pasture/Hay	12.1E13	10.9E13	11.9E13	11.4E13	11.8E13	11.3E13	11.7E13	11.7E13	11.4E13	11.9E13	11.6E13	12.1E13	14.0E14
Commercial	13.1E09	11.8E09	13.1E09	12.6E09	13.1E09	12.6E09	13.1E09	13.1E09	12.6E09	13.1E09	12.6E09	13.1E09	15.4E10
LAX	31.0E11	28.0E11	41.6E11	53.3E11	55.1E11	63.6E11	65.7E11	65.7E11	53.3E11	41.6E11	40.2E11	31.0E11	57.0E12
Open Space	18.6E11	16.8E11	18.6E11	18.0E11	18.6E11	18.0E11	18.6E11	18.6E11	18.0E11	18.6E11	18.0E11	18.6E11	21.9E12
Wetland	67.2E11	60.7E11	67.2E11	65.0E11	67.2E11	65.0E11	67.2E11	67.2E11	65.0E11	67.2E11	65.0E11	67.2E11	79.1E12

Table C. 3 Current conditions of land applied fecal coliform load of Beggars Bridge Creek (sub 6):

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Residential	81.3E10	72.8E10	79.2E10	76.0E10	77.9E10	74.7E10	75.8E10	75.8E10	73.3E10	75.1E10	73.3E10	78.5E10	91.4E11
Wetland	18.7E11	16.9E11	18.7E11	18.1E11	18.7E11	18.1E11	18.7E11	18.7E11	18.1E11	18.7E11	18.1E11	18.7E11	22.0E12
Cropland	25.9E11	23.4E11	25.9E11	25.0E11	25.9E11	25.0E11	25.9E11	25.9E11	25.0E11	25.9E11	25.0E11	25.9E11	30.5E12
Forest	31.5E10	28.4E10	31.5E10	30.5E10	31.5E10	30.5E10	31.5E10	31.5E10	30.5E10	31.5E10	30.5E10	31.5E10	37.1E11
Pasture/Hay	16.0E12	14.5E12	16.0E12	15.5E12	16.0E12	15.5E12	16.0E12	16.0E12	15.5E12	16.0E12	15.5E12	16.0E12	18.9E13
LAX	10.3E10	92.7E09	10.9E10	11.2E10	11.6E10	11.8E10	12.2E10	12.2E10	11.2E10	10.9E10	10.5E10	10.3E10	13.2E11
Open Space	15.8E10	14.3E10	15.8E10	15.3E10	15.8E10	15.3E10	15.8E10	15.8E10	15.3E10	15.8E10	15.3E10	15.8E10	18.6E11

Table C. 4 Current conditions of land applied fecal coliform load of Muddy Creek and Ashville Bridge Creek (subs 5, 7, and 8):

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Residential	28.1E11	25.2E11	27.7E11	26.7E11	27.5E11	26.5E11	27.2E11	27.2E11	26.3E11	27.1E11	26.3E11	27.6E11	32.4E12
Wetland	31.1E11	28.1E11	31.1E11	30.1E11	31.1E11	30.1E11	31.1E11	31.1E11	30.1E11	31.1E11	30.1E11	31.1E11	36.6E12
Cropland	48.2E11	43.5E11	48.2E11	46.7E11	48.2E11	46.7E11	48.2E11	48.2E11	46.7E11	48.2E11	46.7E11	48.2E11	56.8E12
Forest	84.6E10	76.4E10	84.6E10	81.9E10	84.6E10	81.9E10	84.6E10	84.6E10	81.9E10	84.6E10	81.9E10	84.6E10	99.6E11
Pasture/Hay	47.1E11	42.5E11	47.0E11	45.3E11	46.8E11	45.2E11	46.7E11	46.7E11	45.3E11	47.0E11	45.5E11	47.1E11	55.2E12
LAX	20.6E10	18.6E10	21.7E10	22.4E10	23.1E10	23.4E10	24.2E10	24.2E10	22.4E10	21.7E10	21.0E10	20.6E10	26.4E11
Open Space	48.3E10	43.6E10	48.3E10	46.7E10	48.3E10	46.7E10	48.3E10	48.3E10	46.7E10	48.3E10	46.7E10	48.3E10	56.9E11

Table C. 5 Current conditions of land applied fecal coliform load of Hell Point Creek (upper + lower) (subs 9, 10, and 11):

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Residential	35.0E12	31.6E12	35.0E12	33.9E12	35.0E12	33.9E12	35.0E12	35.0E12	33.8E12	35.0E12	33.8E12	35.0E12	41.2E13
Cropland	92.5E10	83.5E10	92.5E10	89.5E10	92.5E10	89.5E10	92.5E10	92.5E10	89.5E10	92.5E10	89.5E10	92.5E10	10.9E12
Forest	12.4E11	11.2E11	12.4E11	12.0E11	12.4E11	12.0E11	12.4E11	12.4E11	12.0E11	12.4E11	12.0E11	12.4E11	14.6E12
Pasture/Hay	15.8E11	14.3E11	15.7E11	15.2E11	15.7E11	15.1E11	15.6E11	15.6E11	15.2E11	15.7E11	15.2E11	15.8E11	18.5E12
Commercial	20.3E10	18.3E10	20.3E10	19.6E10	20.3E10	19.6E10	20.3E10	20.3E10	19.6E10	20.3E10	19.6E10	20.3E10	23.9E11
LAX	90.1E09	81.4E09	94.4E09	96.6E09	99.8E09	10.1E10	10.4E10	10.4E10	96.6E09	94.4E09	91.3E09	90.1E09	11.4E11
Open Space	25.9E11	23.4E11	25.9E11	25.1E11	25.9E11	25.1E11	25.9E11	25.9E11	25.1E11	25.9E11	25.1E11	25.9E11	30.5E12
Wetland	69.7E11	63.0E11	69.7E11	67.5E11	69.7E11	67.5E11	69.7E11	69.7E11	67.5E11	69.7E11	67.5E11	69.7E11	82.1E12
Barren	20.7E09	18.7E09	20.7E09	20.0E09	20.7E09	20.0E09	20.7E09	20.7E09	20.0E09	20.7E09	20.0E09	20.7E09	24.4E10

Table C. 6 Monthly, directly deposited fecal coliform loads in each reach of North Landing River (subs 1, 2, and 3):

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	1	24.7E10	22.3E10	24.7E10	23.9E10	24.7E10	23.9E10	24.7E10	24.7E10	23.9E10	24.7E10	23.9E10	24.7E10	29.1E11
Livestock	1	14.6E09	13.2E09	19.5E09	28.3E09	29.2E09	33.0E09	34.1E09	34.1E09	28.3E09	19.5E09	18.9E09	14.6E09	28.7E10
Wildlife	1	54.0E10	48.8E10	54.0E10	52.2E10	54.0E10	52.2E10	54.0E10	54.0E10	52.2E10	54.0E10	52.2E10	54.0E10	63.6E11
Human/Pet	2	63.1E10	57.0E10	63.1E10	61.0E10	63.1E10	61.0E10	63.1E10	63.1E10	61.0E10	63.1E10	61.0E10	63.1E10	74.3E11
Livestock	2	31.0E08	28.0E08	41.4E08	60.1E08	62.1E08	70.1E08	72.4E08	72.4E08	60.1E08	41.4E08	40.1E08	31.0E08	61.0E09
Wildlife	2	45.8E10	41.4E10	45.8E10	44.3E10	45.8E10	44.3E10	45.8E10	45.8E10	44.3E10	45.8E10	44.3E10	45.8E10	53.9E11
Human/Pet	3	12.1E11	10.9E11	12.1E11	11.7E11	12.1E11	11.7E11	12.1E11	12.1E11	11.7E11	12.1E11	11.7E11	12.1E11	14.2E12
Livestock	3	70.9E09	64.0E09	94.5E09	13.7E10	14.2E10	16.0E10	16.5E10	16.5E10	13.7E10	94.5E09	91.4E09	70.9E09	13.9E11
Wildlife	3	92.5E10	83.5E10	92.5E10	89.5E10	92.5E10	89.5E10	92.5E10	92.5E10	89.5E10	92.5E10	89.5E10	92.5E10	10.9E12

Table C. 7 Monthly, directly deposited fecal coliform loads in each reach of Pocaty River (sub 4):

Source Type	**Reach ID**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Annual Total Loads (cfu/yr)**
Human/Pet	4	82.3E10	74.3E10	82.3E10	79.6E10	82.3E10	79.6E10	82.3E10	82.3E10	79.6E10	82.3E10	79.6E10	82.3E10	96.9E11
Livestock	4	27.7E10	25.0E10	36.9E10	53.5E10	55.3E10	62.4E10	64.5E10	64.5E10	53.5E10	36.9E10	35.7E10	27.7E10	54.4E11
Wildlife	4	10.1E11	90.8E10	10.1E11	97.3E10	10.1E11	97.3E10	10.1E11	10.1E11	97.3E10	10.1E11	97.3E10	10.1E11	11.8E12

Table C. 8 Monthly, directly deposited fecal coliform loads in each reach of Beggars Bridge Creek (sub 6):

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	6	82.3E09	74.3E09	82.3E09	79.6E09	82.3E09	79.6E09	82.3E09	82.3E09	79.6E09	82.3E09	79.6E09	82.3E09	96.9E10
Livestock	6	15.5E08	14.0E08	20.6E08	29.9E08	30.9E08	34.9E08	36.1E08	36.1E08	29.9E08	20.6E08	19.9E08	15.5E08	30.4E09
Wildlife	6	11.8E10	10.7E10	11.8E10	11.4E10	11.8E10	11.4E10	11.8E10	11.8E10	11.4E10	11.8E10	11.4E10	11.8E10	13.9E11

Table C. 9 Monthly, directly deposited fecal coliform loads in each reach of Muddy Creek and Ashville Bridge Creek (subs 5, 7, and 8):

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	5	27.4E09	24.8E09	27.4E09	26.5E09	27.4E09	26.5E09	27.4E09	27.4E09	26.5E09	27.4E09	26.5E09	27.4E09	32.3E10
Livestock	5	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00
Wildlife	5	68.2E09	61.6E09	68.2E09	66.0E09	68.2E09	66.0E09	68.2E09	68.2E09	66.0E09	68.2E09	66.0E09	68.2E09	80.3E10
Human/Pet	7	82.3E09	74.3E09	82.3E09	79.6E09	82.3E09	79.6E09	82.3E09	82.3E09	79.6E09	82.3E09	79.6E09	82.3E09	96.9E10
Livestock	7	15.5E08	14.0E08	20.6E08	29.9E08	30.9E08	34.9E08	36.1E08	36.1E08	29.9E08	20.6E08	19.9E08	15.5E08	30.4E09
Wildlife	7	74.7E09	67.5E09	74.7E09	72.3E09	74.7E09	72.3E09	74.7E09	74.7E09	72.3E09	74.7E09	72.3E09	74.7E09	88.0E10
Human/Pet	8	82.3E09	74.3E09	82.3E09	79.6E09	82.3E09	79.6E09	82.3E09	82.3E09	79.6E09	82.3E09	79.6E09	82.3E09	96.9E10
Livestock	8	13.3E08	12.0E08	17.7E08	25.7E08	26.6E08	30.0E08	31.0E08	31.0E08	25.7E08	17.7E08	17.1E08	13.3E08	26.1E09
Wildlife	8	12.4E10	11.2E10	12.4E10	12.0E10	12.4E10	12.0E10	12.4E10	12.4E10	12.0E10	12.4E10	12.0E10	12.4E10	14.6E11

Table C. 10 Monthly, directly deposited fecal coliform loads in each reach of Hell Point Creek Bridge Creek (subs 9, 10, and 11):

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	9	27.4E09	24.8E09	27.4E09	26.5E09	27.4E09	26.5E09	27.4E09	27.4E09	26.5E09	27.4E09	26.5E09	27.4E09	32.3E10
Livestock	9	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00
Wildlife	9	10.1E10	91.6E09	10.1E10	98.2E09	10.1E10	98.2E09	10.1E10	10.1E10	98.2E09	10.1E10	98.2E09	10.1E10	11.9E11
Human/Pet	10	27.4E09	24.8E09	27.4E09	26.5E09	27.4E09	26.5E09	27.4E09	27.4E09	26.5E09	27.4E09	26.5E09	27.4E09	32.3E10
Livestock	10	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00
Wildlife	10	77.8E09	70.2E09	77.8E09	75.3E09	77.8E09	75.3E09	77.8E09	77.8E09	75.3E09	77.8E09	75.3E09	77.8E09	91.6E10
Human/Pet	11	30.2E10	27.2E10	30.2E10	29.2E10	30.2E10	29.2E10	30.2E10	30.2E10	29.2E10	30.2E10	29.2E10	30.2E10	35.5E11
Livestock	11	11.1E08	10.0E08	14.8E08	21.5E08	22.2E08	25.1E08	25.9E08	25.9E08	21.5E08	14.8E08	14.3E08	11.1E08	21.8E09
Wildlife	11	49.8E10	45.0E10	49.8E10	48.2E10	49.8E10	48.2E10	49.8E10	49.8E10	48.2E10	49.8E10	48.2E10	49.8E10	58.6E11

Table C. 11 Existing annual (2012) loads from land-based sources of North Landing River (subs 1, 2, and 3):

Source	Residential	Cropland	Commercial	Lax	Openspace	Wetland	Barren	Water	Forest
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.23E+10	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	1.02E+13	0.00E+00	0.00E+00	0.00E+00	1.13E+12	0.00E+00
Beef_calves	0.00E+00	0.00E+00	0.00E+00	2.12E+12	0.00E+00	0.00E+00	0.00E+00	2.35E+11	0.00E+00
Beef_replacements	0.00E+00	0.00E+00	0.00E+00	3.34E+12	0.00E+00	0.00E+00	0.00E+00	3.71E+11	0.00E+00
Cats	1.52E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	1.15E+13	1.81E+13	0.00E+00	5.02E+11	8.57E+12	7.12E+13	0.00E+00	0.00E+00	1.48E+13
Dogs	1.70E+15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	1.23E+10	6.02E+09	2.60E+08	5.71E+08	9.05E+09	1.12E+10	1.23E+08	0.00E+00	3.31E+09
Geese	6.54E+11	3.21E+11	1.38E+10	3.04E+10	4.82E+11	5.96E+11	6.57E+09	0.00E+00	1.76E+11
Muskrat	5.29E+13	2.59E+13	1.12E+12	2.46E+12	3.90E+13	4.82E+13	5.31E+11	0.00E+00	1.42E+13
Nutria_Adult	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.33E+12	0.00E+00
Nutria_Youth	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.73E+12	0.00E+00
People_on_straight_pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.45E+13	0.00E+00
People_on_failing_septics	1.37E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	1.18E+14	4.99E+13	2.43E+12	1.53E+12	8.67E+13	1.40E+14	1.42E+12	0.00E+00	3.57E+13
Turkey	0.00E+00	1.89E+09	0.00E+00	5.24E+07	0.00E+00	2.97E+10	0.00E+00	0.00E+00	6.20E+09
Total	**1.90E+15**	**9.42E+13**	**3.56E+12**	**2.02E+13**	**1.35E+14**	**2.60E+14**	**1.96E+12**	**3.83E+13**	**6.49E+13**

Table C. 12 Existing annual (2012) loads from land-based sources of Pocaty River (sub 4):

Source	Residential	Cropland	Commercial	Lax	Openspace	Wetland	Barren	Water	Forest
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.21E+10	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	3.20E+13	0.00E+00	0.00E+00	0.00E+00	3.55E+12	0.00E+00
Beef_calves	0.00E+00	0.00E+00	0.00E+00	6.58E+12	0.00E+00	0.00E+00	0.00E+00	7.31E+11	0.00E+00
Beef_replacements	0.00E+00	0.00E+00	0.00E+00	1.04E+13	0.00E+00	0.00E+00	0.00E+00	1.15E+12	0.00E+00
Cats	5.11E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	2.70E+11	3.58E+13	0.00E+00	8.96E+11	1.29E+12	1.77E+13	0.00E+00	0.00E+00	6.69E+12
Dogs	5.72E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	2.89E+08	1.29E+10	5.50E+06	1.02E+09	1.45E+09	4.26E+09	5.23E+07	0.00E+00	2.15E+09
Geese	1.54E+10	6.88E+11	2.93E+08	5.43E+10	7.70E+10	2.27E+11	2.78E+09	0.00E+00	1.14E+11
Muskrat	1.24E+12	5.56E+13	2.37E+10	4.39E+12	6.23E+12	1.83E+13	2.25E+11	0.00E+00	9.24E+12
Nutria_Adult	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.12E+12	0.00E+00
Nutria_Youth	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.79E+12	0.00E+00
People_on_straight _pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.69E+12	0.00E+00
People_on_failing_ septics	7.52E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	2.94E+12	1.04E+14	1.30E+11	2.74E+12	1.43E+13	4.28E+13	5.44E+11	0.00E+00	1.79E+13
Turkey	0.00E+00	3.73E+09	0.00E+00	9.36E+07	0.00E+00	7.38E+09	0.00E+00	0.00E+00	2.79E+09
Total	**6.92E+13**	**1.96E+14**	**1.54E+11**	**5.71E+13**	**2.19E+13**	**7.90E+13**	**7.72E+11**	**2.11E+13**	**3.39E+13**

Table C. 13 Existing annual (2012) loads from land-based sources of Beggars Bridge Creek (sub 6):

Source	Residential	Cropland	Commercial	Lax	Openspace	Wetland	Barren	Water	Forest
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E+09	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	1.92E+11	0.00E+00	0.00E+00	0.00E+00	2.13E+10	0.00E+00
Beef_calves	0.00E+00	0.00E+00	0.00E+00	3.16E+10	0.00E+00	0.00E+00	0.00E+00	3.51E+09	0.00E+00
Beef_replacements	0.00E+00	0.00E+00	0.00E+00	4.99E+10	0.00E+00	0.00E+00	0.00E+00	5.54E+09	0.00E+00
Cats	6.55E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	1.69E+10	5.75E+12	0.00E+00	1.16E+11	1.12E+11	4.09E+12	0.00E+00	0.00E+00	6.46E+11
Dogs	7.33E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	1.82E+07	1.88E+09	0.00E+00	1.32E+08	1.15E+08	1.38E+09	0.00E+00	0.00E+00	2.59E+08
Geese	9.70E+08	1.00E+11	0.00E+00	7.05E+09	6.11E+09	7.34E+10	0.00E+00	0.00E+00	1.38E+10
Muskrat	7.85E+10	8.11E+12	0.00E+00	5.70E+11	4.94E+11	5.93E+12	0.00E+00	0.00E+00	1.12E+12
Nutria_Adult	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+11	0.00E+00
Nutria_Youth	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.72E+11	0.00E+00
People_on_straight_pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.69E+11	0.00E+00
People_on_failing_septics	1.51E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	2.01E+11	1.65E+13	0.00E+00	3.56E+11	1.25E+12	1.19E+13	0.00E+00	0.00E+00	1.93E+12
Turkey	0.00E+00	6.01E+08	0.00E+00	1.22E+07	0.00E+00	1.71E+09	0.00E+00	0.00E+00	2.70E+08
Total	**9.14E+12**	**3.05E+13**	**0.00E+00**	**1.32E+12**	**1.86E+12**	**2.20E+13**	**0.00E+00**	**1.43E+12**	**3.71E+12**

Table C. 14 Existing annual (2012) loads from land-based sources of Muddy Creek and Ashville Bridge Creek (subs 5, 7, and 8):

Source	Residential	Cropland	Commercial	Lax	Openspace	Wetland	Barren	Water	Forest
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E+10	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	3.46E+11	0.00E+00	0.00E+00	0.00E+00	3.84E+10	0.00E+00
Beef_calves	0.00E+00	0.00E+00	0.00E+00	6.32E+10	0.00E+00	0.00E+00	0.00E+00	7.03E+09	0.00E+00
Beef_replacements	0.00E+00	0.00E+00	0.00E+00	9.97E+10	0.00E+00	0.00E+00	0.00E+00	1.11E+10	0.00E+00
Cats	2.42E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	1.67E+11	1.02E+13	0.00E+00	2.36E+11	3.17E+11	6.94E+12	0.00E+00	0.00E+00	1.93E+12
Dogs	2.71E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	2.13E+08	3.81E+09	0.00E+00	2.69E+08	3.84E+08	2.25E+09	0.00E+00	0.00E+00	6.15E+08
Geese	1.13E+10	2.03E+11	0.00E+00	1.43E+10	2.05E+10	1.20E+11	0.00E+00	0.00E+00	3.28E+10
Muskrat	9.17E+11	1.64E+13	0.00E+00	1.16E+12	1.66E+12	9.69E+12	0.00E+00	0.00E+00	2.65E+12
Nutria_Adult	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.40E+11	0.00E+00
Nutria_Youth	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.89E+11	0.00E+00
People_on_straight_pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E+12	0.00E+00
People_on_failing_septics	2.28E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	1.95E+12	3.00E+13	0.00E+00	7.22E+11	3.69E+12	1.98E+13	0.00E+00	0.00E+00	5.34E+12
Turkey	0.00E+00	1.07E+09	0.00E+00	2.47E+07	0.00E+00	2.90E+09	0.00E+00	0.00E+00	8.07E+08
Total	**3.24E+13**	**5.68E+13**	**0.00E+00**	**2.64E+12**	**5.69E+12**	**3.66E+13**	**0.00E+00**	**3.56E+12**	**9.95E+12**

Table C. 15 Existing annual (2012) loads from land-based sources of Hell Point Creek (subs 9, 10, and 11):

Source	Residential	Cropland	Commercial	Lax	Openspace	Wetland	Barren	Water	Forest
Beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E+10	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	1.15E+11	0.00E+00	0.00E+00	0.00E+00	1.28E+10	0.00E+00
Beef_calves	0.00E+00	0.00E+00	0.00E+00	3.16E+10	0.00E+00	0.00E+00	0.00E+00	3.51E+09	0.00E+00
Beef_replacements	0.00E+00	0.00E+00	0.00E+00	4.99E+10	0.00E+00	0.00E+00	0.00E+00	5.54E+09	0.00E+00
Cats	3.22E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	3.32E+12	2.09E+12	0.00E+00	1.05E+11	2.07E+12	1.78E+13	0.00E+00	0.00E+00	3.12E+12
Dogs	3.60E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	3.45E+09	6.98E+08	1.38E+08	1.19E+08	1.93E+09	4.56E+09	5.50E+06	0.00E+00	7.85E+08
Geese	1.84E+11	3.72E+10	7.34E+09	6.36E+09	1.03E+11	2.43E+11	2.93E+08	0.00E+00	4.18E+10
Muskrat	1.49E+13	3.01E+12	5.93E+11	5.14E+11	8.32E+12	1.96E+13	2.37E+10	0.00E+00	3.38E+12
Nutria_Adult	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E+12	0.00E+00
Nutria_Youth	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.31E+12	0.00E+00
People_on_straight_pipes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.20E+12	0.00E+00
People_on_failing_septics	7.97E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	3.29E+13	5.76E+12	1.79E+12	3.21E+11	2.00E+13	4.44E+13	2.20E+11	0.00E+00	8.08E+12
Turkey	0.00E+00	2.18E+08	0.00E+00	1.10E+07	0.00E+00	7.44E+09	0.00E+00	0.00E+00	1.30E+09
Total	**4.12E+14**	**1.09E+13**	**2.39E+12**	**1.14E+12**	**3.05E+13**	**8.21E+13**	**2.44E+11**	**9.40E+12**	**1.46E+13**

Table C. 16 Existing annual loads from direct-deposition sources of North Landing River (subs 1, 2, and 3):

Source	Annual Total Loads (cfu/yr)
beaver	52.3E09
beef	11.3E11
Beef calves	23.5E10
Beef replacements	37.1E10
deer	32.8E10
duck	17.3E08
geese	60.6E09
horses	00E00
muskrat	90.0E11
Nutria Adult	43.3E11
Nutria Youth	77.3E11
People on straight pipes	24.5E12
raccoon	11.3E11
turkey	96.5E06

Table C. 17 Existing annual loads from direct-deposition sources of Pocaty River (sub 4):

Source	Annual Total Loads (cfu/yr)
beaver	32.1E09
beef	35.5E11
Beef calves	73.1E10
Beef replacements	11.5E11
deer	18.6E10
duck	98.4E07
geese	34.5E09
horses	00E00
muskrat	51.3E11
Nutria Adult	21.2E11
Nutria Youth	37.9E11
People on straight pipes	96.9E11
raccoon	55.0E10
turkey	38.1E06

Table C. 18 Existing annual loads from direct-deposition sources of Beggars Bridge Creek (sub 6):

Source	Annual Total Loads (cfu/yr)
beaver	50.4E08
beef	21.3E09
Beef calves	35.1E08
Beef replacements	55.4E08
deer	30.4E09
duck	16.1E07
geese	56.3E08
horses	00E00
muskrat	83.7E10
Nutria Adult	15.0E10
Nutria Youth	27.2E10
People on straight pipes	96.9E10
raccoon	90.1E09
turkey	68.6E05

Table C. 19 Existing annual loads from direct-deposition sources of Muddy Creek and Ashville Bridge Creek (subs 5, 7, and 8):

Source	Annual Total Loads (cfu/yr)
beaver	10.3E09
beef	38.4E09
Beef calves	70.3E08
Beef replacements	11.1E09
deer	56.0E09
duck	32.0E07
geese	11.2E09
horses	00E00
muskrat	16.7E11
Nutria Adult	44.0E10
Nutria Youth	78.9E10
People on straight pipes	22.6E11
raccoon	17.2E10
turkey	12.7E06

Table C. 20 Existing annual loads from direct-deposition sources of Hell Point Creek (subs 9, 10, and 11):

Source	Annual Total Loads (cfu/yr)
beaver	14.2E09
beef	12.8E09
Beef calves	35.1E08
Beef replacements	55.4E08
deer	73.6E09
duck	46.4E07
geese	16.3E09
horses	00E00
muskrat	24.2E11
Nutria Adult	18.5E11
Nutria Youth	33.1E11
People on straight pipes	42.0E11
raccoon	29.0E10
turkey	22.7E06

Page intentionally blank

APPENDIX D

Phosphorus Modeling Procedure: Linking the Sources to the Endpoint

MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT- Phosphorus

Modeling Framework Selection - GWLF

Total phosphorus concentrations exceeded national screening levels and were determined to be a significant contributor to the low dissolved oxygen concentrations in the Pocaty River and Ashville Bridge Creek study areas. A reference watershed approach was used in this study to develop a total phosphorus TMDL for the study areas in the Pocaty River and Ashville Bridge Creek study areas. A Feeder Ditch to Dismal Swamp from Lake Drummond was used as the reference watershed in this study (MapTech, 2006). For modeling phosphorus, it was necessary to also model sediment, which constitutes one of the vehicles through which phosphorus is transported.

A watershed model was used to simulate phosphorus loads from potential sources in impaired and in the reference watersheds. The model used in this study was the *Visual Basic™* version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The GWLF model was developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in ungaged watersheds. The model also included modifications made by Yagow et al., 2002 and BSE, 2003. Numeric endpoints were based on unit-area loading rates calculated for the reference watershed. The TMDL was then developed for the impaired watershed based on these endpoints and the results from load allocation scenarios.

GWLF is a continuous simulation, spatially lumped model that operates on a daily time step for water balance calculations and monthly calculations for sediment and nutrients from daily water balance. The continuity of the model simulation allows for accounting for seasonal variability in precipitation. In addition to runoff and sediment, the model simulates dissolved and attached nitrogen and phosphorus loads delivered to streams from watersheds with both point and nonpoint sources of pollution. The model considers flow input from both surface and groundwater. Land use classes are used as the basic unit for representing variable source areas. The calculation of nutrient loads from septic systems, stream-bank erosion from livestock access, and the inclusion of sediment and nutrient loads from point sources are also supported. Runoff is simulated based on the Soil Conservation Service's Curve Number method (SCS, 1986). Erosion is calculated from a modification of the Universal Soil Loss Equation (USLE) (Schwab et al., 1981; Wischmeier and Smith, 1978). Sediment estimates use a delivery ratio based on a function of watershed area and erosion estimates from the modified USLE. The sediment transported depends on the transport capacity of runoff.

The model uses three input files for weather, transport, and nutrient loads. The weather file contains daily temperature and precipitation for the period of record. Data were based on a water year starting in October and ending in September. The transport file contains input data related to hydrology and sediment transport. The nutrient file contains nutrient values for the various land uses, point sources, and septic system types, and also urban sediment buildup rates.

GWLF Model Setup

Watershed data needed to run GWLF used in this study were generated using GIS spatial coverage, local weather data, streamflow data, literature values, and other data. Subwatersheds are not required to run the GWLF model. For the total phosphorus TMDL development, the total area for the reference watershed was equated to the area of impaired watershed. To accomplish this, the area of land use categories in reference watershed was proportionately decreased based on the percentage land use distribution.

The GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as land use/land cover, topography, and soils. In essence, the model uses a form of the hydrologic units (HU) concept to estimate runoff, sediment, and nutrients from different pervious areas (HUs) in the watershed (Li, 1975; England, 1970). In the GWLF model, the nonpoint source load calculation for sediment is affected by land use activity (*e.g.*, farming practices), topographic parameters, soil characteristics, soil cover conditions, stream channel conditions, livestock access, and weather. The model uses land use categories as the mechanism for defining homogeneity of source areas. This is a variation of the HU concept, where homogeneity in hydrologic response or nonpoint source pollutant response would typically involve the identification of soil land use topographic conditions that would be expected to give a homogeneous response to a given rainfall input. A number of parameters are included in the model to index the effect of varying soil-topographic conditions by land use entities.

Land Use and Land Cover

Land use distributions for the Pocaty River study area and for the area-adjusted Feeder Ditch watersheds are given in Table D.1. Table D.2 shows the same information for Ashville Bridge Creek study area. Land use acreage for the reference watershed was adjusted up by the ratio of impaired watershed to reference watershed maintaining the original land use distribution. These areas were used for modeling phosphorus.

Table D.1 Land use areas used in the GWLF model for the Pocaty River and area-adjusted Feeder Ditch watersheds.

Source Land Use	Pocaty River Watershed (ha)[1]	Area-Adjusted Feeder Ditch Watershed (ha)
Pervious Area:		
Barren	13.92	46.23
Conventional tillage	1,400.22	359.23
Conservation tillage	1,611.00	359.23
Forest	518.38	2,623.20
Disturbed forest	44.58	81.13
Open space	399.37	--
Hay	353.90	13.34
Unimproved pasture	358.30	413.39
Cattle grazed pasture	334.64	17.78
Water	212.64	349.03
Wetland	1,486.93	2,521.46
Commercial	0.72	0.41
Residential	59.97	--
Developed	--	51.76
Impervious Area:		
Developed	--	22.18
Commercial	2.88	0.61
Residential	30.89	--
Open Space	34.73	--
Barren	1.05	5.14
Watershed Total	6,864.12	6,864.12

[1] 1ha = 2.47 ac

Table D.2 Land use areas used in the GWLF model for the Ashville Bridge Creek and area-adjusted Feeder Ditch watersheds.

Source Land Use	Pocaty River Watershed (ha)[1]	Area-Adjusted Feeder Ditch Watershed (ha)
Pervious Area:		
Barren	--	5.65
Conventional tillage	224.29	43.89
Conservation tillage	86.79	43.89
Forest	79.75	320.54
Disturbed forest	4.98	9.91
Open space	37.07	--
Hay	11.15	1.63
Unimproved pasture	85.86	50.51
Cattle grazed pasture	6.00	2.17
Water	27.85	42.64
Wetland	222.52	308.07
Commercial	0.00	0.05
Residential	36.54	--
Developed		6.32
Impervious Area:		
Developed	--	2.71
Commercial	0.00	0.07
Residential	13.52	--
Open Space	2.36	0.63
Barren	--	0.63
Watershed Total	838.68	838.68

[1] 1ha = 2.47 ac

Stream Flow and Weather Data

Daily precipitation data was available near the study area at the Wallaceton Lk Drummond NCDC COOP station # 448837, Suffolk Lake Kilby NCDC COOP station #448192, and Norfolk South NCDC COOP station # 446147.

Stream flow data was not available in the study area. While the model used in this study was designed for use in ungaged watersheds, having adequate stream flow data for calibrating the model is beneficial. Only several months worth of stream flow data were available in recent years at a nearby station on Albemarle Canal just upstream of the confluence with the North Landing River (USGS flow station 02043120).

Modeling Parameters – Sediment and Phosphorus

Sediment parameters include USLE erodibility factor (K), length of slope (LS), cover crop factor (C), and practice factor (P), sediment delivery ratio, and a buildup and loss functions for impervious surfaces. The product of the USLE parameters, KLSCP, is entered as input to GWLF. Soils data for the watersheds were obtained from the Soil Survey Geographic (SSURGO) database for Virginia (SCS, 2013). The K factor relates to a soil's inherent erodibility and affects the amount of soil erosion from a given field. The area-weighted K-factor by land use category was calculated using GIS procedures. Land slope was calculated from USGS National Elevation Dataset data using GIS techniques. The length of slope was based on GIS procedures developed by MapTech using procedures recommended by Wischmeier and Smith (1978). The area-weighted LS factor was calculated for each land use category. The weighted C-factor for each land use category was estimated following guidelines given in Wischmeier and Smith, 1978, GWLF User's Manual (Haith et al., 1992) and Kleene, 1995. The management practice factor (P) was set at 1.0 for all land except for conservation tillage land where it was set to 0.5.

The model also requires phosphorus parameters in the nutrient file. The GWLF user manual was the main source of information for identifying such parameters. The nutrient file requires information on the phosphorus content of sediment, groundwater, and septic system effluent. Dissolved phosphorus concentrations of flow from different land uses are also available from the user manual. Plant uptake of phosphorus, as well as the number of failing septic systems, are also included in the model.

The sediment delivery ratio specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size. The sediment delivery ratios for impaired and reference watersheds were calculated as an inverse function of watershed size (Evans et al., 2001).

The runoff curve number is a function of soil type, antecedent moisture conditions, and cover and management practices. The runoff potential of a specific soil type is indexed by the Soil Hydrologic Group (SHG) code. Each soil-mapping unit is assigned SHG codes that range in increasing runoff potential from A to D. The SHG code was given a numerical value of 1 to 4 to index SHG codes A to D, respectively. An area-weighted average SHG code was calculated for each land use/land cover from soil survey data using GIS techniques. Runoff curve numbers (CN) for SHG codes A to D were assigned to each land use/land cover condition for antecedent moisture condition II following GWLF guidance documents and SCS, 1986 recommended procedures. The runoff CN for each land use/land cover condition then was adjusted based on the numeric area-weighted SHG codes. Tables D.3 and D.4 show the curve number and the KLSCP product for the Pocaty River study area and Ashville Bridge Creek study area and reference watersheds.

Table D.3 The GWLF curve numbers and KLSCP values for existing conditions in the Pocaty River and area-adjusted Feeder Ditch watersheds.

Source	Pocaty River		Area-Adjusted Feeder Ditch	
	CN	KLSCP	CN	KLSCP
Pervious Area:				
Barren	88.14	0.005038	86.52	0.010846
Conventional tillage	85.2	0.00715	83.48	0.012855
Conservation tillage	83.2	0.001574	81.48	0.005661
Forest	73.62	0.000033	73.77	0.000034
Disturbed forest	80.1	0.001938	80.23	0.002012
Open space	74.31	0.001027	--	--
Hay	74.98	0.000079	71.65	0.000144
Unimproved pasture	81.84	0.00149	79.46	0.002696
Cattle grazed pasture	77.41	0.000258	74.56	0.000467
Water	98	0	98	0.000000
Wetland	74.85	0.000149	76.17	0.0001
Commercial	74.18	0.000093	77.01	0.000106
Residential	74.61	0.000252	--	--
Developed	--	--	74.20	0.000405
Impervious Area:				
Developed	--	--	98	0.000405
Commercial	98	0.000093	98	0.000106
Residential	98	0.000252	--	--
Open Space	98	0.001027	--	--
Barren	98	0.005038	98	0.010846

Table D.4 The GWLF curve numbers and KLSCP values for existing conditions in the Asheville Bridge Creek and area-adjusted Feeder Ditch watersheds.

Source	Asheville Bridge Creek		Area-Adjusted Feeder Ditch	
	CN	KLSCP	CN	KLSCP
Pervious Area:				
Barren	90.00	0.000000	86.52	0.010846
Conventional tillage	85.22	0.007326	83.48	0.012855
Conservation tillage	83.22	0.001613	81.48	0.005661
Forest	74.04	0.000028	73.77	0.000034
Disturbed forest	80.46	0.001625	80.23	0.002012
Open space	74.28	0.001036	--	--
Hay	74.51	0.000087	71.65	0.000144
Unimproved pasture	81.51	0.001629	79.46	0.002696
Cattle grazed pasture	77.01	0.000282	74.56	0.000467
Water	98.00	0.000000	98	0.000000
Wetland	75.02	0.000127	76.17	0.0001
Commercial	77.00	0.000000	77.01	0.000106
Residential	77.52	0.000243	--	--
Developed	--	--	74.20	0.000405
Impervious Area:				
Developed	--	--	98	0.000405
Commercial	98	0.000000	98	0.000106
Residential	98	0.000243	--	--
Barren	--	--	98	0.010846

Evapotranspiration (ET) cover coefficients were entered by month. Monthly ET cover coefficients were assigned each land use/land cover condition following procedures outlined in Novotny and Chesters (1981) and GWLF guidance. Area-weighted ET cover coefficients were then calculated for each sediment source class. These values were then adjusted from the hydrologically calibrated values of previous projects in the area.

Selection of Representative Modeling Period

Due to the lack of observed flow data, a complete analysis of historic stream flow was not possible. Analysis of historic precipitation showed that the years 2001 through 2003 were suitable since they included a high, medium, and low total precipitation.

GWLF Hydrology Calibration

Flow data were not available for the study areas and therefore, flow data from the nearby Albemarle Canal were used utilizing paired-watershed approach. In paired-watershed approach, initial hydrologic parameters are estimated for both watersheds. Hydrologic parameters are adjusted in the watershed with observed flow data during the calibration process. Similar adjustments are then made to the hydrologic parameters in the watershed with no flow data. Flow data were available for USGS station 02043120 on Albemarle Canal just upstream of the confluence with Northwest River.

Estimating Total Phosphorus Loads

Point Sources

There are currently no individual VPDES permits within either one of the study areas. There is one general domestic permit in the Pocaty River impaired watershed and none in the reference watershed. The general permitted point source was assumed to discharge at a design flow of 1,000 gallons per day and a total phosphorus concentration of 2.5 mg/L resulting in 3.45 kilograms of phosphorus per year. There are also two municipal storm water permits for Chesapeake Bay and Virginia Beach that discharge within the watershed.

Nonpoint Sources

The annual phosphorus load from the impaired watersheds as well as the reference watershed was estimated using the Generalized Watershed Loading Functions (GWLF) model. Phosphorus loading from nonpoint sources is a function of the land use. Sediment load is calculated and phosphorus is attached to sediment. Phosphorus is also assumed to be in dissolved phase with runoff water and groundwater. The land cover in the Pocaty River and Asheville Bridge Creek drainage area was characterized using the 2006 NLCD.

Septic Systems/Straight Pipes

Population, housing units, and type of sewage treatment from U.S. Census Bureau (USCB, 1990, 2000) were calculated using GIS. In the U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank, or a cesspool or the sewage is disposed of in some other way. The Census category "Other Means" includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. Ten percent of the houses included in this category were assumed to be disposing of sewage via straight pipes.

The accuracy of the initial estimates was enhanced by obtaining geographic information from counties detailing the locations of septic systems. Adjustments were made to initial estimates of total number of houses and number of houses with septic systems based on county data. The number of houses with failing septic systems was estimated based on the assumption that each septic systems fails, on average, once during an expected lifetime of 30 years. Resulting estimates were shared with regions Health Departments and feedback was obtained and used in adjusting numbers.

Phosphorus concentration recommended in the model's user manual of 14 mg/L for septic system effluent was multiplied by the average number of people per household times the daily wastewater of 75 gallons per person per day. The total load from straight pipes is the product of wastewater per person, wastewater phosphorus concentration, and the total number of straight pipes in the watershed. Table D.5 shows the number of failing septic systems and straight pipes within the study areas and the reference watershed.

Table D.5 Estimated numbers of failing septic systems and straight pipes.

Watershed	Number of Failing Septic Systems	Number of Straight pipes
Pocaty River	84	1.3
Ashville Bridge Creek	3	< 1
Feeder Ditch	129	41

Load from MS4

There are two municipal separate storm sewer systems (MS4) permits in the impaired watersheds in Virginia Beach and Chesapeake areas. The Ashville Bridge Creek study area is entirely within the Virginia Beach portion of the watershed while the Pocaty River study area is mostly within the Chesapeake portion of the watershed. The area governed by the two permits was estimated as the impervious portion of the developed lands in the watershed. Phosphorus load governed by the MS4s from these areas was estimated in a similar way as the load from the other land uses where phosphorus build-up was assumed on these areas, which was available for wash-off during storm events.

APPENDIX E

Low Dissolved Oxygen (DO) & pH Assessment for Pocaty River and Ashville Bridge Creek

Low Dissolved Oxygen (DO) & pH Assessment for Pocaty River and Ashville Bridge Creek

BACKGROUND

The Clean Water Act (CWA) that became law in 1972 requires that all U.S. streams, rivers, and lakes meet certain water quality standards. The CWA also requires that states conduct monitoring to identify waters that are polluted or do not otherwise meet standards. Through this required program, the state of Virginia has found that many stream segments do not meet state water quality standards for protection of the six beneficial uses: recreation/swimming, aquatic life, wildlife, fish consumption, shellfish consumption, and public water supply (drinking).

When streams fail to meet standards, Section 303(d) of the CWA and the U.S. Environmental Protection Agency's (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) both require that states develop a Total Maximum Daily Load (TMDL) for each pollutant. A TMDL is a "pollution budget" for a stream; that is, it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS).

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the *"Board shall develop and implement a plan to achieve fully supporting status for impaired waters"*. The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process. Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

The study area for this project is in the Virginia Beach and Chesapeake areas. The impaired segments include Ashville Bridge Creek (lower), and the Pocaty River (**Figure E.1**). The Virginia Department of Environmental Quality (VADEQ) has identified all of these segments as impaired with regard to dissolved oxygen. For the purposes of this report, this watershed shall be referred to as the Back Bay and North Landing River Tributaries study area.

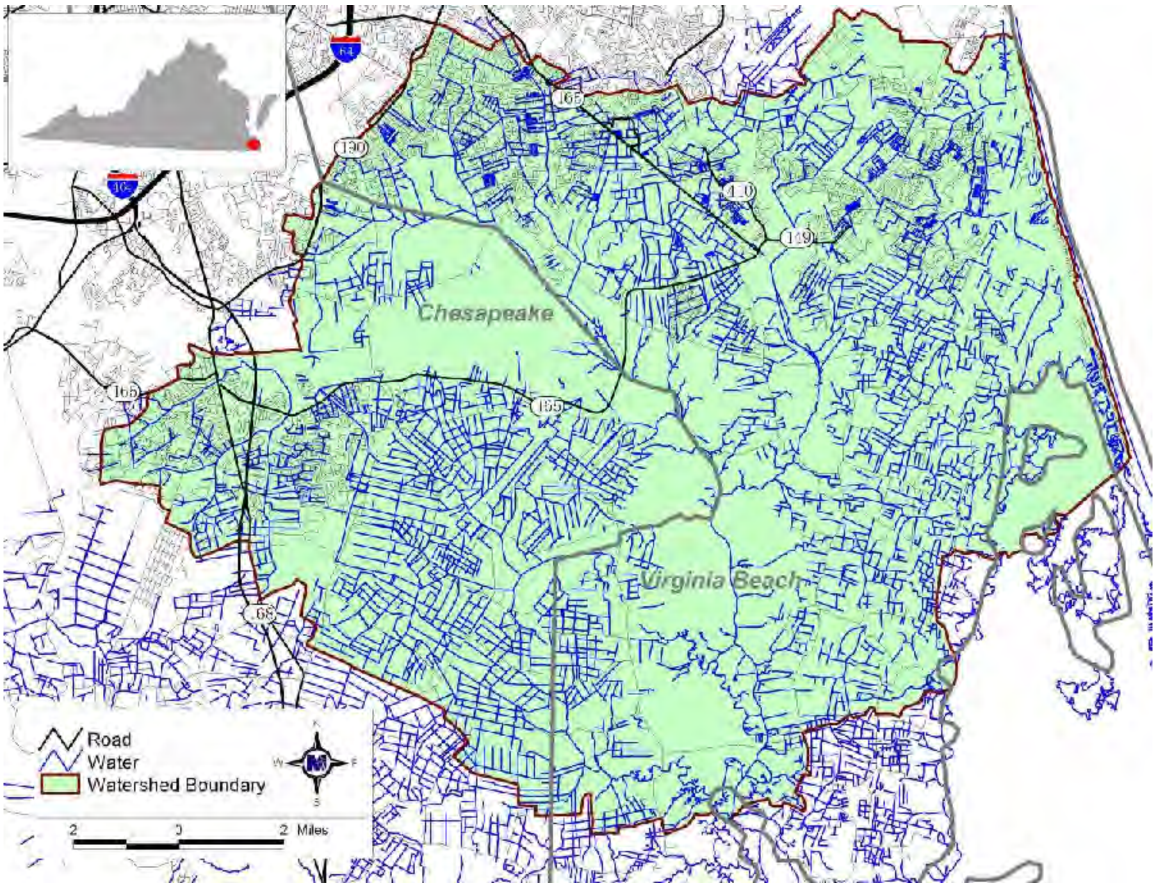

Figure E.1 Location of the Back Bay and North Landing River Tributaries study area watersheds.

Table E. 1 lists, for each impairment, the VADEQ water quality monitoring station used for impaired waters assessment, the initial year that the segment was listed in the Section 303(d) list and miles affected in the 2010 listing. **Figure E.2** shows the current impaired segments and Table E. 1 provides supporting information for each impairment.

Ashville Bridge Creek (VAT-K42E_ASH01A06) first listed in 2006 and the Pocaty River (VAT-K41R_PCT01A02) first listed in 2002 for violations of the minimum dissolved oxygen (DO) water quality standard. In addition Ashville Bridge Creek was listed in 2010 for violations of the minimum pH water quality standard.

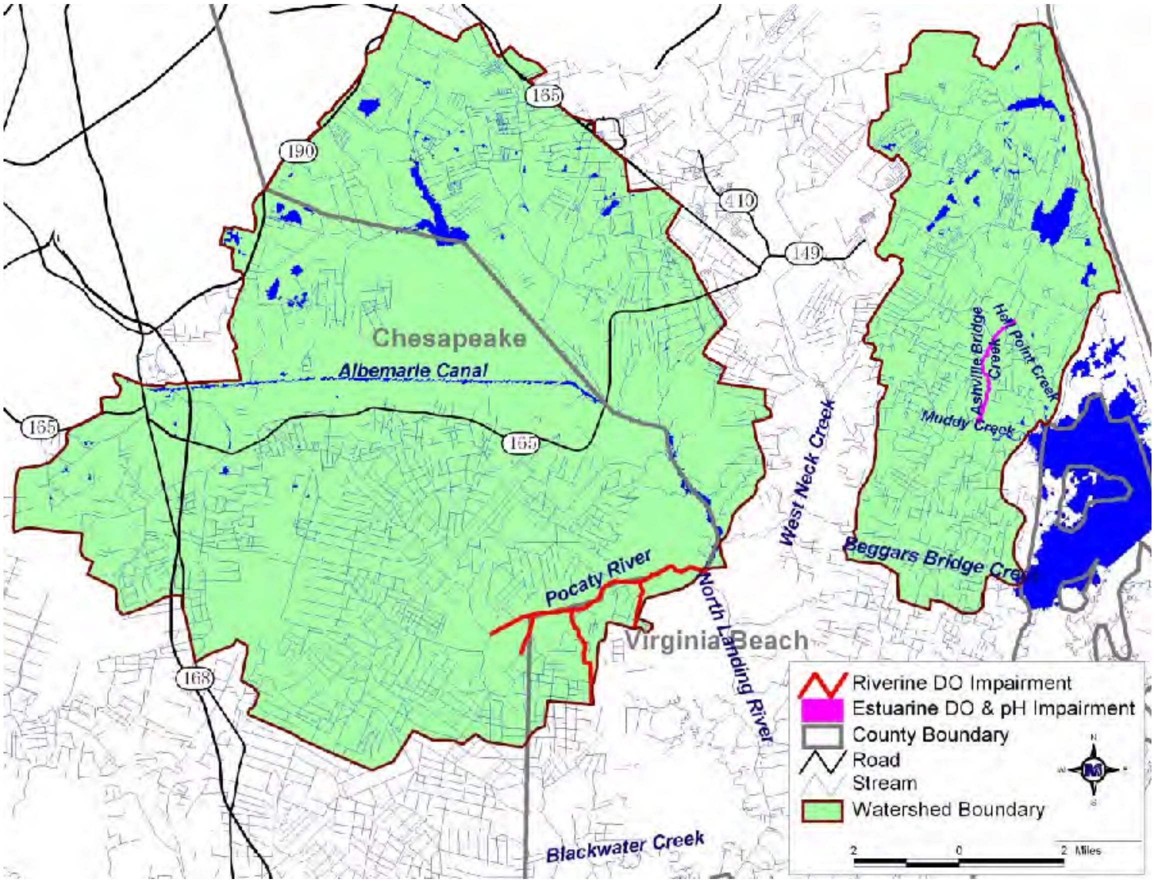

Figure E.2 Impaired stream segments in the Back Bay and North Landing River Tributaries study area.

Table E. 1 Dissolved oxygen and pH impairments on the *2008 Section 305(b)/303(d) Water Quality Integrated Report* within the Back Bay and North Landing River study area.

Stream Name HUP	Listing Station ID(s)	Initial Listing Year	River Miles or Estuary (sq miles)	2010 303(d) List Dissolved Oxygen Violations/ Total Samples	Location
Ashville Bridge Creek - Lower VAT-K42E_ASH01A06	5BASH002.20	2006 2010[*]	0.022[**]	5/36 4/36[*]	The lower portion of Ashville Bridge Creek, between Hell Point and Muddy Creeks.
Pocaty River VAT-K41R_PCT01A02	5BPCT001.79	2002	7.24	16/36	The Pocaty River and selected tribs. from headwaters at mile 3.92 to confluence with North Landing River at river mile 0.00.

[*] pH impairment
[**] Estuary

Back Bay and North Landing River Study Area Watershed Characteristics

The Back Bay and North Landing River study area watershed is entirely located within the level III Middle Atantic Coastal Plain ecoregion. The level IV subsets are the Chesapeake-Pamlico Lowlands and Tidal Marshes and Virginia Beach Barrier Islands. Streams in this level III ecoregion are "universally low in elevation and is characterized by nearly flat terrain, terraces, tidal marshes, ponds, and swampy streams." Brackish wetlands are common and serve as habitat for fish, shellfish, and wildfowl. Elevations range from 0 to 50 feet (0-15 m) and relief is less than 35 feet (11 m); surrounding ecoregions are both higher and better drained.

Streams are usually low in gradient, sluggish, tidally influenced, poorly incised, and lack a defined channel; they are fed by shallow groundwater aquifers and become brackish as they begin to mix with salt water. Wide riparian wetlands occur and channelization is common. Stream water is often high in both natural acidity and dissolved organic carbon and is often stained. (http://www.eoearth.org/article/Ecoregions_of_Delaware%2C_Maryland%2C_Pennsylvania%2C_Virginia%2C_and_West_Virginia_(EPA).

As for the climatic conditions in the study area watersheds, during the period from 1946 to 2010 Norfolk WSO Airport, Virginia (NCDC station# 446139) received an average annual precipitation of approximately 45.65 inches, with 57% of the precipitation occurring during the May through October growing season (SERCC, 2011). Average annual snowfall is 7.8 inches, with the highest snowfall occurring during January (SERCC, 2011). The highest average daily temperature of 87.3 ºF occurs in July, while the lowest average daily temperature of 32.6 ºF occurs in January (SERCC, 2011).

Water Quality Assessment Applicable Water Quality Standards

According to 9 VAC 25-260-5 of Virginia's State Water Control Board *Water Quality Standards*, the term "water quality standards" means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act."

As stated in Virginia state law 9 VAC 25-260-10 (Designation of uses),

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

Virginia's current water quality standards, with the 2010 amendments, require the following for dissolved oxygen concentrations and pH measurements. See **Table E. 2**.

Table E. 2 VAC 25-260-50. Numerical criteria for dissolved oxygen, pH, and maximum temperature

CLASS	DESCRIPTION OF WATERS	Dissolved Oxygen (mg/L) Min	Dissolved Oxygen (mg/L) Daily Avg	pH	Maximum Temperature (°C)
I	Open Ocean	5.0	--	6.0-9.0	--
II	Tidal Waters in the Chowan Basin and the Atlantic Ocean	4.0	5.0	6.0-9.0	--
II	Tidal waters in the Chesapeake Bay and its tidal tributaries	see VAC 25-260-185		6.0-9.0	
III	Nontidal Waters Coastal and Piedmont Zones	4.0	5.0	6.0-9.0	32
IV	Mountainous Zones Waters	4.0	5.0	6.0-9.0	31
V	Stockable Trout Waters	5.0	6.0	6.0-9.0	21
VI	Natural Trout Waters	6.0	7.0	6.0-9.0	20
VII	Swamp Waters	*	*	4.3-9.0*	**

*This classification recognizes that the natural quality of these waters may fall outside of the ranges for D.O. and pH set forth above as water quality criteria; therefore, on a case-by-case basis, criteria for specific Class VII waters can be developed which reflect the natural quality of the waterbody. Virginia Pollutant Discharge Elimination System limitations in Class VII waters shall meet pH of 6.0 - 9.0.
** Maximum temperature will be same for Classes I through VI waters as appropriate.

The dissolved oxygen and pH criteria used in developing the dissolved oxygen and pH TMDL(s) in this study is outlined in Class II (Tidal waters in the Chowan Basin and Atlantic Ocean) in the table above.

Discussion of In-Stream Water Quality

This section provides an inventory and analysis of available observed in-stream monitoring data in the Back Bay and North Landing River Tributaries study area watersheds. An examination of data from water quality stations used in the 303(d) assessment was. Sources of data and pertinent results are discussed.

Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- DO, pH, temperature, oxygen demand indicators, orgnic solids and nutrient samples from four VADEQ in-stream monitoring stations,

VADEQ Water Quality Monitoring for TMDL Assessment

Data from in-stream water samples, collected at VADEQ monitoring stations from January 2000 through March 2011 (**Figure E.3**) were analyzed for dissolved oxygen, pH, conductivity, biochemical oxygen demand (BOD_5), total organic solids, temperature, nitrate-nitrogen (NO3-N), total nitrogen (TN) and total phosphorus (TP) (**Table E. 3 – Table E. 11**). Dissolved oxygen and pH measurements were made for the express purpose of determining compliance with the state water quality standards. There are currently no water quality standards for temperature, nutrients, total organic solids, conductivity and BOD_5. **Table E. 3 – Table E. 11** summarize the dissolved oxygen, pH, temperature, nitrate nitrogen, total nitrogen, total phosphorus, BOD_5 and conductivity results from the in-stream monitoring stations. The tables are arranged in alphabetical order by stream name then from downstream to upstream station location. A discussion of pertinent water quality parameters will follow.

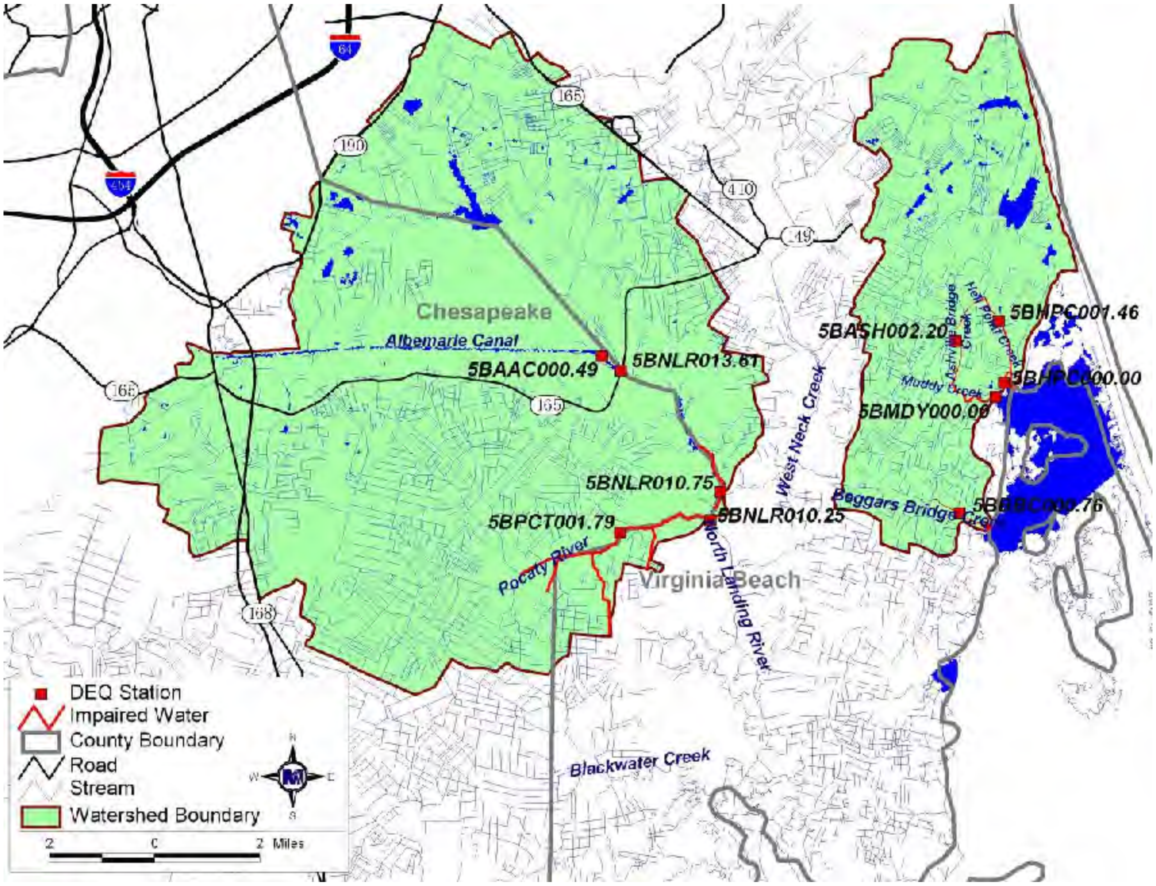

Figure E.3 Location of VADEQ water quality monitoring stations in the Back Bay, North Landing River and Pocaty River watersheds.

Table E. 3 Summary of DO (mg/L) data collected by VADEQ from January 2000 - March 2011.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %[1]
Ashville Bridge Creek	5BASH002.20	8/2002 - 9/2006	42	2.3	13.9	7.0	6.3	3.0	14.3%
Pocaty River	5BPCT001.79	1/2000 - 3/2011	76	0.7	11.4	4.8	4.2	2.9	46.1%
Pocaty River	5BPCT002.16	4/2003 - 11/2003	2	0.8	5.2	3.0	3.0	3.1	50.0%

[1] Based on a VADEQ minimum water quality standard of 4.0 (mg/L).

Table E. 4 Summary of pH (std units) data collected by VADEQ from January 1998 - August 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %[1]
Ashville Bridge Creek	5BASH002.20	8/2002 - 9/2006	42	5.7	8.3	6.6	6.5	0.5	9.5%
Pocaty River	5BPCT001.79	1/2000 - 3/2011	77	6.2	7.3	6.7	6.7	0.2	0.0%
Pocaty River	5BPCT002.16	4/2003 - 11/2003	2	6.6	7.3	6.9	6.9	0.6	0.0%

[1] Based on a VADEQ minimum water quality standard of 6.0 (mg/L).

Table E. 5 Summary of Temperature (°celsius) data collected by VADEQ from January 1998 - August 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %[1]
Ashville Bridge Creek	5BASH002.20	8/2002 - 9/2006	42	1.4	32.5	18.3	19.3	9.0	NA
Pocaty River	5BPCT001.79	1/2000 - 3/2011	77	1.1	27.7	15.7	14.6	7.3	NA
Pocaty River	5BPCT002.16	4/2003 - 11/2003	2	16.9	17.3	17.1	17.1	0.3	NA

[1] There is no maximum temperature standard for Class II waters.

Table E. 6 Summary of NO3-N (mg/L) data collected by VADEQ from January 1998 - August 2006.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Exceeds Screening Value %[1]
Pocaty River	5BPCT001.79	1/2000 - 5/2003	30	0.04	3.43	0.38	0.12	0.69	16.7%
Pocaty River	5BPCT002.16	4/2003	1	0.48	0.48	0.48	NA	NA	0.0%

[1] The USGS screening value for NO_3-N is 0.6 mg/L.

Table E. 7 Summary of TN (mg/L) data collected by VADEQ from January 1998 - May 2009.

Stream	**Station**	**Date**	**Count**	**Minimum**	**Maximum**	**Mean**	**Median**	**Standard Deviation**	**Exceeds Screening Value %[1]**
Ashville Bridge Creek	5BASH002.20	5/2003 - 9/2006	21	0.2	2.6	1.3	1.3	0.5	23.8%
Pocaty River	5BPCT001.79	7/2003 - 1/2011	46	0.5	7.7	1.4	1.2	1.1	80.4%

[1] The USGS screening value for TN is 1.0 mg/L.

Table E. 8 Summary of TP (mg/L) data collected by VADEQ from January 1998 - May 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Exceeds Screening Value %[1]
Ashville Bridge Creek	5BASH002.20	5/2003 - 9/2006	22	0.04	0.22	0.14	0.13	0.05	22.7%
Pocaty River	5BPCT001.79	1/2000 - 3/2011	77	0.07	0.67	0.24	0.20	0.14	85.7%
Pocaty River	5BPCT002.16	4/2003	1	0.25	0.25	0.25	NA	NA	100.0%

[1] The USGS screening value for TP is 0.1 mg/L.

Table E. 9 Summary of BOD_5 (mg/L) data collected by VADEQ from January 1998 - July 2001.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %[1]
Pocaty River	5BPCT001.79	1/2000 - 6/2001	18	2.0	7.0	2.4	2.0	1.2	NA

[1] there is no water quality standard for BOD_5.

Table E. 10 Summary of Conductivity (μmhos/cm) data collected by VADEQ from January 1998 – May 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %[1]
Ashville Bridge Creek	5BASH002.20	8/2002 - 9/2006	42	62	6,960	969	555	1,276	NA
Pocaty River	5BPCT001.79	1/2000 - 3/2011	77	140	7,596	1,320	517	1,770	NA
Pocaty River	5BPCT002.16	4/2003 - 11/2003	2	330	334	332	332	3	NA

[1] there is no water quality standard for conductivity.

Table E. 11 Summary of Total Organic Solids (mg/L) data collected by VADEQ from January 1998 - May 2003

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %[1]
Pocaty River	5BPCT001.79	1/2000 - 5/2003	30	47	990	156	89	182	NA
Pocaty River	5BPCT002.16	04/22/03	1	75	75	75	NA	NA	NA

[1] there is no water quality standard for total organic solids.

Assessment of Natural Conditions

This chapter utilizes the approach for determining the level to which DO and pH impaired streams are impacted by natural conditions, and the resulting justification for proceeding with TMDL development or choosing an alternative path (*e.g.*, revision of the water quality standard) (MapTech, 2003). The procedure developed by MapTech requires four specific criteria be applied to an impaired stream to determine whether the impairment is naturally occurring or the result of anthropogenic activities. The four criteria are described below:

1. Are wetlands present in the impaired segment? Natural conditions associated with low dissolved oxygen (DO) and low pH involve slow moving streams with little slope that have high dissolved organic matter and have a brownish-yellow color. The breakdown of organic matter can deplete oxygen concentrations, and the organic acids that are produced lower the pH.

2. Are there excessive nutrients in the stream? High nutrient concentrations can cause reductions in dissolved oxygen concentrations by accelerating the rate of organic matter decomposition in streams. USGS (1999) estimated national background nutrient concentrations in streams and groundwater from undeveloped areas. Average nitrate background concentrations are less than 0.6 mg/L for streams, average total nitrogen (TN) background concentrations are less than 1.0 mg/L, and average background concentrations of total phosphorus (TP) are less than 0.1 mg/L. Streams with average concentrations of nutrients greater than the national background concentrations are considered to have impacts from anthropogenic sources.

3. Does DO vary seasonally (i.e., oxygen deficit in the summer)? Anthropogenic impacts on DO will likely disrupt the typical seasonal fluctuation seen in the DO concentrations of wetland streams. A weak

seasonal pattern could indicate that human inputs from point or nonpoint sources are impacting the seasonal cycle.

4. Is there evidence of human impact that warrants the development of a TMDL? Point sources should be identified and analyzed to determine if there is any impact on the stream DO or pH concentrations. Violations of other water quality standards (e.g., benthic, *E. coli*) for a stream segment could indicate that anthropogenic sources are affecting the DO and/or pH levels. Land use analysis can also be a valuable tool for identifying potential human impacts.

Following the application of the four criteria listed above, four outcomes are possible and are noted below:

1. If one or more of the four analyses indicate the presence of an anthropogenic source, and the indicators of natural causes are NOT present, then natural conditions are NOT likely, and TMDL development should be pursued.

2. If one or more of the four analyses indicate the presence of an anthropogenic source, but the indicators of natural causes are present, then natural conditions are likely being compounded by anthropogenic sources, and TMDL development should be pursued.

3. If none of the four analyses indicate the presence of an anthropogenic source, but the indicators of natural causes are NOT present, then natural conditions are NOT likely, and TMDL development should be pursued.

4. If none of the four analyses indicate the presence of an anthropogenic source, and the indicators of natural causes are present, then natural conditions are likely, and a change in the water quality standard should be pursued.

Ashville Bridge Creek

Ashville Bridge Creek was assessed as not supporting the Aquatic Life Use designation on Virginia's 2006 303(d) list based on violations of VADEQ's water quality standards for minimum dissolved oxygen concentrations and minimum pH measurements. DO water quality standard violations were recorded at monitoring station 5BASH002.20 August 2002 and September 2006. **Figure E.4** shows DO concentrations at VADEQ monitoring station 5BASH002.20.

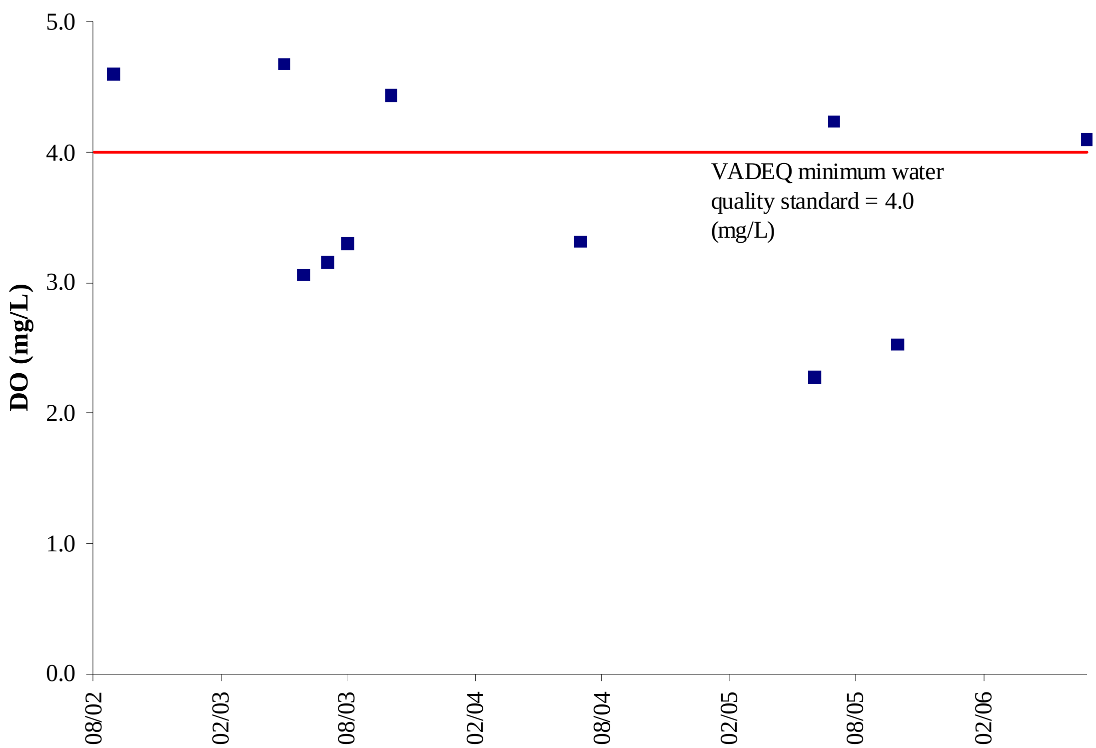

Figure E.4 DO concentrations at VADEQ monitoring station 5BASH002.20.

There were four pH measurements below the minimum water quality standard of 6.0 std units between September 2003 through October 2005 at VADEQ water quality monitoring station 5BASH002.20. **Figure E.5** shows pH measurements at VADEQ water quality monitoring station 5BASH002.20.

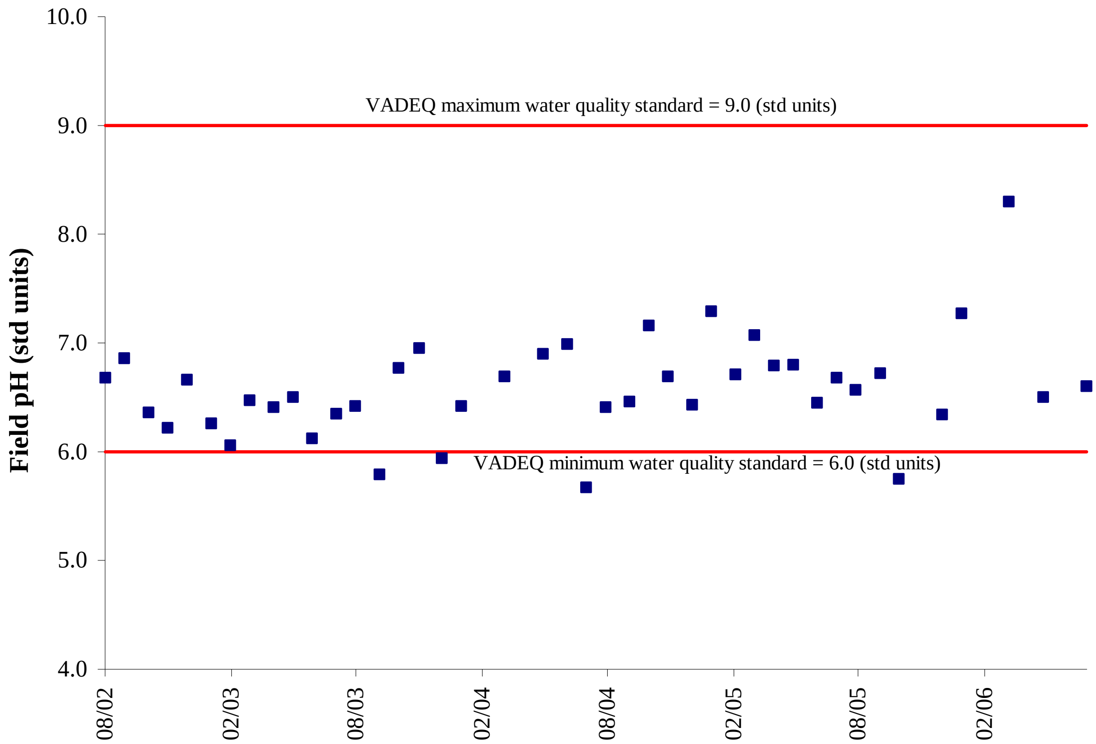

Figure E.5 pH measurements at VADEQ monitoring station 5BASH002.20.

It is clear from the figures above that low dissolved oxygen and pH are chronic problems in Ashville Bridge Creek. From the methodology developed by MapTech (MapTech, 2003) four decisions are to be made in assessing anthropogenic impacts on the low DO concentrations and pH measurements in the Ashville Bridge Creek.

Question 1. Are wetlands present in the impaired segment of the stream?

A site visit to Ashville Bridge Creek on October 3, 2011 revealed very swampy conditions in the watershed. The stream had highly colored water indicating a high level of dissolved organics in the water. A water sample was collected at the VADEQ monitoring site (5BASH002.20) and analyzed by use of Fluorometric analysis to determine the presence of dissolved organics. The color of swamp water results from the decomposition of plant material that produces compounds such as fulvic and humic acids. One way to confirm the presence of fulvic and humic acids is through the use of fluorometry. Fluorescence has been used for purposes ranging from detecting detergent whiteners to determining the origin of petroleum spills in harbors. Fluorescence is a luminescence usually in the ultra violet or blue region of the spectrum. It does not occur in all compounds and requires that a fluorophore be present in a substance. A fluorophore absorbs energy of a specific wavelength and re-emits energy at a different and specific wavelength. The amount and wavelength of the emitted energy depend on both the fluorophore and the chemical environment of the fluorophore. Therefore, fluorescent substances have distinct specific wavelengths and can be identified with the proper equipment and techniques. The results of the analysis can be used to generate 3-dimensional images referred to as an excitation-emission matrixes or EEMs.

Standard Fulvic Acid is a fluorescent substance used in studies where the dissolved organic matter in a stream originates from soil or swamp/wetland vegetation. That is, Standard Fulvic Acid is a fingerprint for dissolved organic matter of that origin. The "reagent grade" standard, referred to as "Standard Suwannee River Fulvic Acid" (SRFA), is obtained from the International Humic Substance Society. MapTech performed a Fluorometric analysis of a water sample from Ashville Bridge Creek. The EEM is shown in **Figure E.6**. The results indicate a weak fulvic acid presence (no blue and dark blue half moon near a wavelength of 500 nm on the x-axis). This indicates that excess organic matter from the decomposition of plants may not play a significant role in the depressing dissolved oxygen concentrations in Ashville Bridge Creek. It is understood that this one sample represents one snap shot in time.

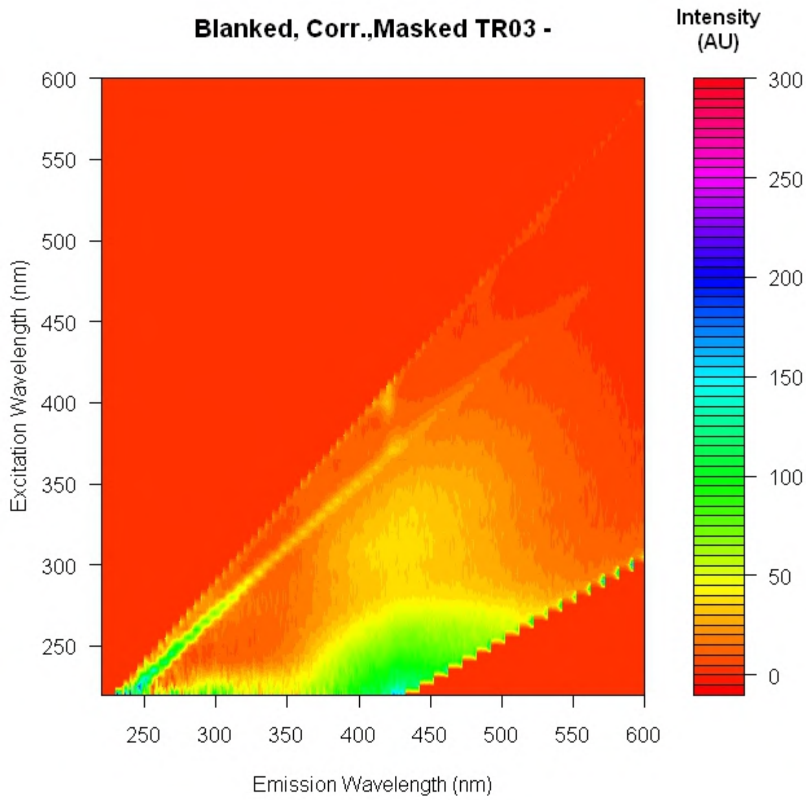

Figure E.6 EEM for the Ashville Bridge Creek upstream from of Rt. 165 bridge at VADEQ monitoring station 5BASH002.20.

Land use within the Ashville Bridge Creek drainage area is approximately 39% agricultural, 20% forest and 15% wetlands. Estimation of the hydrologic slope of the stream is <0.1%. Wetlands were present within the impaired segment of this stream.

Question 2. Are there excessive nutrients in the stream?

Total nitrogen (TN) and total phosphorus (TP) were monitored at VADEQ monitoring station 5BASH002.20 from May 2003 to September 2006 (**Table E. 7** and **Table E. 8**). Mean concentrations of TN, and TP are shown in **Table E. 12**. The nitrate-nitrogen average was well below national criteria. Average TN and TP concentrations exceeded the average background concentrations estimated by the USGS (1999). Nutrients in Ashville Bridge Creek exceed screening levels.

Table E. 12 Average NO3-N, TN and TP concentrations collected by the VADEQ at station 5BASH002.20.

	NO3-N	TN	TP
Station	**Criteria 0.60 (mg/L)**	**Criteria 1.0 (mg/L)**	**Criteria 0.10 (mg/L)**
5BASH002.20	NA	**1.3**	**0.14**

Bold values exceed national criteria.
NA no data available.

Question 3. Does DO vary seasonally (*i.e.*, oxygen deficit in the summer)?

A seasonal analysis of dissolved oxygen data from station 5BASH002.20 was conducted using a Moods median test. This test was used to compare median values of DO in each month. Differences in mean monthly DO concentrations are indicated in **Table E.** 13. DO in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, June and July are in median group "A" and are not significantly different from each other. The results indicate that DO levels in the spring-summer months tend to be lower than DO in the winter months and are therefore not significantly impacted by anthropogenic impacts.

Table E. 13 Summary of Moods median tests on mean monthly DO concentrations at station 5BASH002.20.

Month	Mean (mg/L)	Min (mg/L)	Max (mg/L)	Median Groups[1]		
January	10.35	6.34	13.89			C
February	10.82	9.42	12.22			C
March	10.22	7.64	13.07			C
April	6.69	5.93	7.44		B	
May	6.68	4.68	8.60		B	
June	3.66	2.28	5.64	A		
July	3.71	3.16	4.24	A		
August	5.34	3.30	6.42	A		
September	5.46	4.60	6.00	A		
October	6.13	2.53	10.56	A		
November	7.10	5.01	8.69		B	
December	8.47	5.71	11.85		B	

[1] DO concentrations in months with the same median group letter are not significantly different from each other at the 95% level of significance.

Question 4. Is there evidence of human impact that warrants the development of a TMDL?

No VADEQ permitted discharges discharge directly to Ashville Bridge Creek. There are four VPDES permitted discharges in the vicinity of Ashville Bridge Creek and under the certain tidal conditions effluent from these discharges could reach Ashville Bridge Creek (**Table E.** 14). High nutrient concentrations seem to be the only obvious evidence of human impact in the watershed.

Table E. 14 Summary of VADEQ permits in the Ashville Bridge Creek watershed.

Permit Type	Discharger Type	Permit Number	Facility Name	Receiving or Adjacent Stream
Storm Water Industrial	Industrial Storm Water	VAR050409	Oceana Salvage - Anoia Recycling LLC	Ditch/Canal/UTRIB to Redwing Lake
Storm Water Industrial	Industrial Storm Water	VAR050407	US Navy - NAS - Oceana - Dam Neck Annex	Ditch to Redwing Lake
VPDES Individual	Sanitary Wastewater	VA0062391	Indian Cove Resort Association Incorporated	Hell Point Creek
VPDES Individual	Sanitary Wastewater	VA0081248	HRSD - Atlantic Sewage Treatment Plant	Brinsons Inlet Lake to Back Bay

Conclusion: Based upon nutrient concentrations exceeding screening levels, a nutrient TMDL will be necessary for the Ashville Bridge Creek watershed. A local reference stream with little or no anthropogenic impacts (Appendix F) will be used a reference station for both impaired streams. The stream is the feeder ditch canal from Lake Drummond, and the data were collected at VADEQ monitoring station 5BXCK000.00. **Table E.** 15 shows a comparison of nutrient averages for the reference station and the impaired monitoring station (5BNLR013.61). Based on the higher the total phosphorus concentrations in the impaired stream, the nutrient TMDL will be based on total phosphorus.

Table E. 15 Nutrient averages at VADEQ monitoring stations 5BXCK000.00 and 5BASH002.20.

VADEQ Monitoring Station	NO_3-N	TN	TP
5BXCK000.00	0.29	2.62	0.06
5BASH002.20	NA	1.3	0.14

Pocaty River

The Pocaty River was assessed as not supporting the Aquatic Life Use designation on Virginia's 2010 303(d) list based on water quality monitoring performed at VADEQ monitoring station 5BPCT001.79. Minimum DO water quality standard violations were recorded at 5BPCT001.79 during the 2010 assessment period. **Figure E.7** shows the DO concentrations at VADEQ monitoring station 5BPCT001.79.

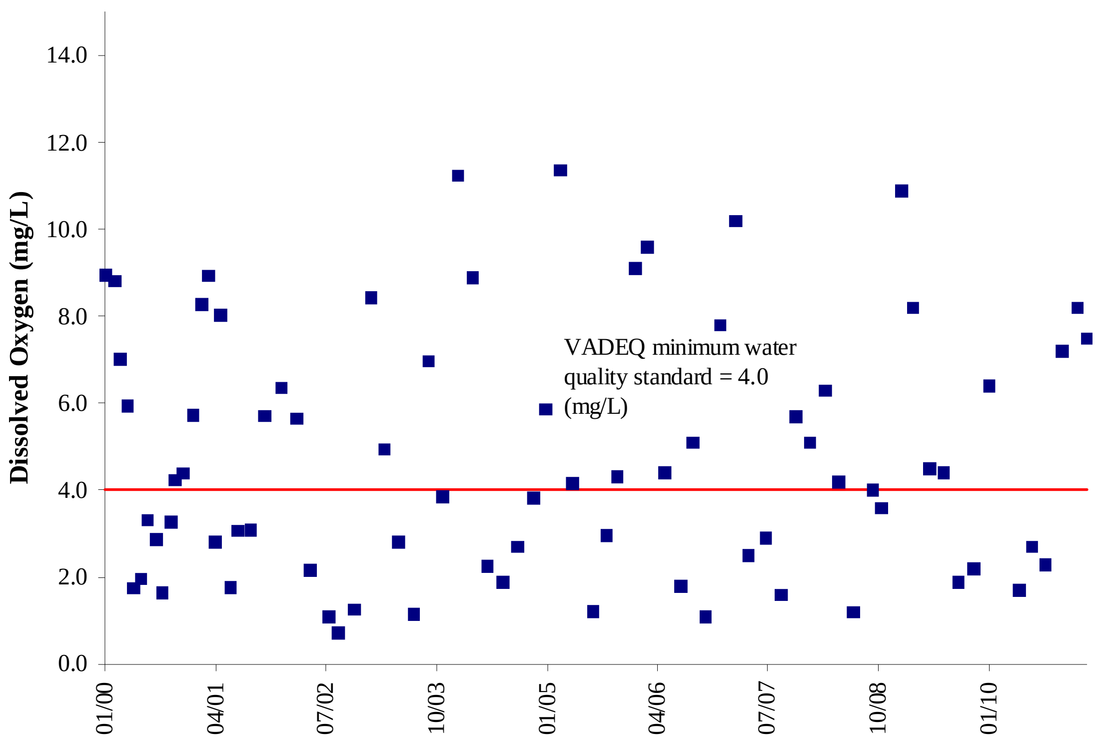

Figure E.7 DO concentrations at VADEQ monitoring station 5BPCT001.79.

It is clear from the figure above that low dissolved oxygen is a chronic problem in the Pocaty River. From the methodology developed by MapTech (MapTech, 2003), four decisions are to be made in assessing anthropogenic impacts on low DO concentrations in the Pocaty River.

Question 1. Are wetlands present in the impaired segment of the stream?

A site visit to the Pocaty River on October 3, 2011 revealed very swampy conditions in the watershed. The highly colored water indicated a high level of dissolved organics in the water. A water sample was collected at the DEQ monitoring site (5BPCT001.79) and analyzed by use of Fluorometric analysis to determine the presence of dissolved organics. The results of the analysis indicate a strong signal for fulvic and humic acids (blue and dark blue half moon near a wavelength of 500 nm on the x-axis), which are the products of wetland area plant decomposition (**Figure E.8**). This suggests that the natural breakdown of organic plant material could be associated with the depressed dissolved oxygen concentrations in the stream.

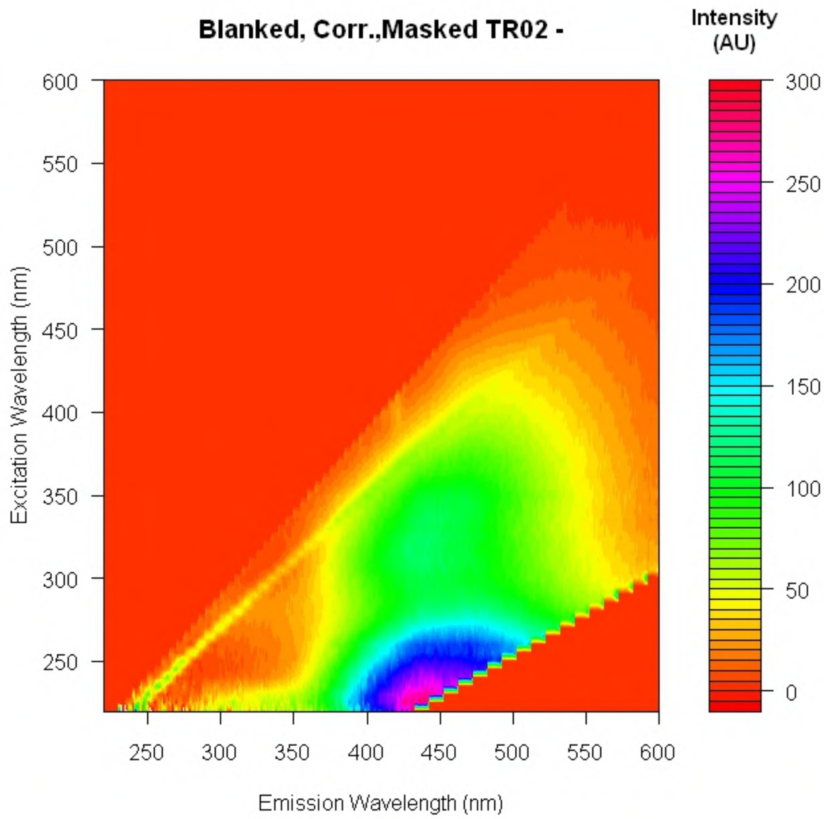

Figure E.8 EEM for the Pocaty River at VADEQ monitoring station 5BPCT001.79.

Land use within the Pocaty River drainage area is approximately 66% agricultural, 16% forest and 9% wetlands. Estimation of the hydrologic slope of the stream is <0.1%. Wetlands are definitely present within the impaired segment drainage area of this stream.

Question 2. Are there excessive nutrients in the stream?

Nitrate-nitrogen (NO3-N), total nitrogen (TN) and total phosphorus (TP) were monitored at VADEQ monitoring station 5BPCT001.79 (**Table E. 6 - Table E. 8**). Mean concentrations of NO3-N, TN, and TP are shown in **Table E.** 16. The average concentrations for NO3-N were below the average background concentration estimated by USGS (1999). However, TN and TP average concentrations exceeded the national background concentrations. Therefore, nutrients in the Pocaty River exceed the screening values.

Table E. 16 Average NO3-N, TN and TP concentrations collected by the VADEQ in the Pocaty River.

Station	NO3-N Critieria 0.60 (mg/L)	TN Critieria 1.0 (mg/L)	TP Critieria 0.10 (mg/L)
5BPCT001.79	0.38	1.40	0.24

Question 3. Does DO vary seasonally (*i.e.*, oxygen deficit in the summer)?

A seasonal analysis of dissolved oxygen data from station 5BPCT001.79 was conducted using a Moods median test. This test was used to compare median values of DO in each month. Differences in mean monthly DO concentrations are indicated in **Table E.** 17. DO in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, January and February are in median group "C" and are not significantly different from each other. The results indicate that DO levels in the spring-summer months tend to be lower than DO in the winter months and are therefore not significantly impacted by anthropogenic impacts.

Table E. 17 Summary of Moods median tests on mean monthly DO concentrations at station 5BPCT001.79.

Month	Mean (mg/L)	Min (mg/L)	Max (mg/L)	Median Groups[1]		
January	7.84	5.10	11.24			C
February	8.55	8.28	8.81			C
March	8.06	4.95	11.37			C
April	4.38	2.81	5.95		B	
May	3.50	1.70	8.04		B	
June	1.87	1.77	1.97	A		
July	2.25	1.10	4.40	A		
August	2.87	2.87	2.87			
September	3.00	0.72	6.98	A		
October	3.44	3.27	3.60		B	
November	3.94	1.10	7.20		B	
December	4.39	4.39	4.39			

[1] DO concentrations in months with the same median group letter are not significantly different from each other at the 95% level of significance.

Question 4. Is there evidence of human impact that warrants the development of a TMDL?

There is one domestic VPDES point source discharge located in the vicinity of the Pocaty River drainage area (**Table E.** 18). Under the right tidal conditions treated effluent could reach the Pocaty River. Domestic discharges are generally for single family homes and discharge less than 1,000 gpd of treated wastewater. There have been occasional spikes in organic matter in the stream, which combined with the high nutrient concentrations is evidence of human impacts.

Table E. 18 Summary of VADEQ permits in the Pocaty River watershed.

Permit Type	Discharger Type	Permit_number	Facility_name	Receiving or Adjacent Stream
VPDES General	Domestic	VAG403065	Battlefield Golf Club at Centerville	North Landing River X-Trib.

Conclusion: Based upon nutrient concentrations exceeding screening levels, a nutrient TMDL will be necessary for the Pocaty River watershed. A local reference stream with little or no anthropogenic impacts will be used a reference station for the impaired stream. The stream is the feeder ditch canal from Lake Drummond, and the data were collected at VADEQ monitoring station 5BXCK000.00. **Table E.** 19 shows a comparison of nutrient averages for the reference station and the impaired monitoring station (5BPCT001.79). Based on the higher total phosphorus concentrations in the impaired stream, the nutrient TMDL will be based on total phosphorus.

Table E. 19 Nutrient averages at VADEQ monitoring stations 5BXCK000.00 and 5BPCT001.79.

VADEQ Monitoring Station	NO_3-N	TN	TP
5BXCK000.00	0.29	2.62	0.06
5BPCT001.79	0.38	1.40	0.24

Appendix E References

Encyclopedia of Earth, ((http://www.eoearth.org/article/Ecoregions_of_Delaware%2C_Maryland%2C_Pennsylvania%2C_Virginia%2C_and_West_Virginia_(EPA) (accessed 12/11/2009).

EPA. 1999. Guidance for Water Quality-Based Decisions: The TMDL Process. http://www.epa.gov/OWOW/tmdl/decisions/dec1c.html

MapTech, 2003. Methodology for Assessing Natural Dissolved Oxygen and pH Impairments.

U.S. Geological Survey, *The Quality of Our Nation's Waters – Nutrients and Pesticides:* U.S. Geological Survey Circular 1225, 82 p, (1999).

SERCC. 2011. Southeast Regional Climate Center. http://water.dnr.state.sc.us/climate/sercc/

VADEQ and VADCR. 1998. Section 303(d) Total Maximum Daily Load Priority List and Report.

VADEQ. 2002. Section 303(d) Report on Impaired Waters.

VADEQ. 2004. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2006. 305(b)/303(d) Integrated Report.

VADEQ. 2008. 305(b)/303(d) Integrated Report.